The BOILER BOOK

of

THE HARTFORD STEAM BOILER INSPECTION & INSURANCE COMPANY

HARTFORD, CONN.

Price, $1.50

ENGINEERING

DEPARTMENT

THE BOILER BOOK

of

The Hartford Steam Boiler Inspection and Insurance Company

A Collection of Reliable Data For Use in the Design and Installation of Boilers and Other Pressure Vessels.

Compiled by H. E. DART, Superintendent of Engineering Department

The Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.

1920

PREFACE

FOR MORE than forty years the designs of the Engineering Department of this Company have been accepted as standards throughout the United States and have been copied into the most authoritative engineering handbooks and textbooks as well as the trade catalogs of the best-known boiler makers and dealers in materials required for boiler construction. We comply with a great many requests for data on boiler design and installation, the sources of inquiry ranging from college professors to firemen, from well-known steel companies and large boiler-shops to steam-fitters, plumbers and brick-masons in small towns, from Canadian Government commissions and English boiler-makers to Cuban sugar plantations, and from wood-pulp mills in Maine to saw-mills in Oregon and cotton plantations in Louisiana.

Our designs and standards have been disseminated principally in the form of blue-prints, over 83,000 prints having been sent out since the Engineering Department was established. As a rule, however, each blue-print covers only one single phase of some particular subject and we have often thought that it would be worth while to assemble some of the more commonly used data in the form of a pamphlet. This idea has been more forcibly brought to our attention since the promulgation of the Boiler Code of the American Society of Mechanical Engineers and its adoption by several states and cities. We adopted the Code as a standard as soon as it was published and made such minor changes in our old drawings, as were needed to comply with its requirements. All our newer drawings, tables, and other data have been designed in accordance with the provisions of the Code and, in view of the many inquiries which we receive regarding the Code and its application, it seems that such data ought to be especially valuable to those who are trying to follow the Code requirements.

With these ideas in mind we have collected and published the data which appears on the following pages for the use of our friends. This little book is not intended as a treatise on boiler design but merely as a collection in convenient form, of data which we have found valuable in our Engineering Department and which we hope will prove of equal value to those who may have occasion to use it. The designs contained herein represent our ideas as to good practice in boiler construction but it should be understood that we necessarily insure many boilers which do not comply therewith.

THE HARTFORD STEAM BOILER INSPECTION
AND INSURANCE COMPANY

Hartford, Conn.
November 20, 1920.

INDEX

BASIC PRINCIPLES.

The general rules and working stresses used in calculating the tables which appear on the following pages, are given below. These values are used in all the work of our Engineering Department.

Minimum factor of safety = 5.

Tensile strength of steel plates = 55000 lbs. per sq. in.

Resistance of steel plates to crushing = 95000 lbs. per sq. in.

Strength of rivets in single shear = 44000 lbs. per sq. in.

Strength of rivets in double shear = 88000 lbs. per sq. in.

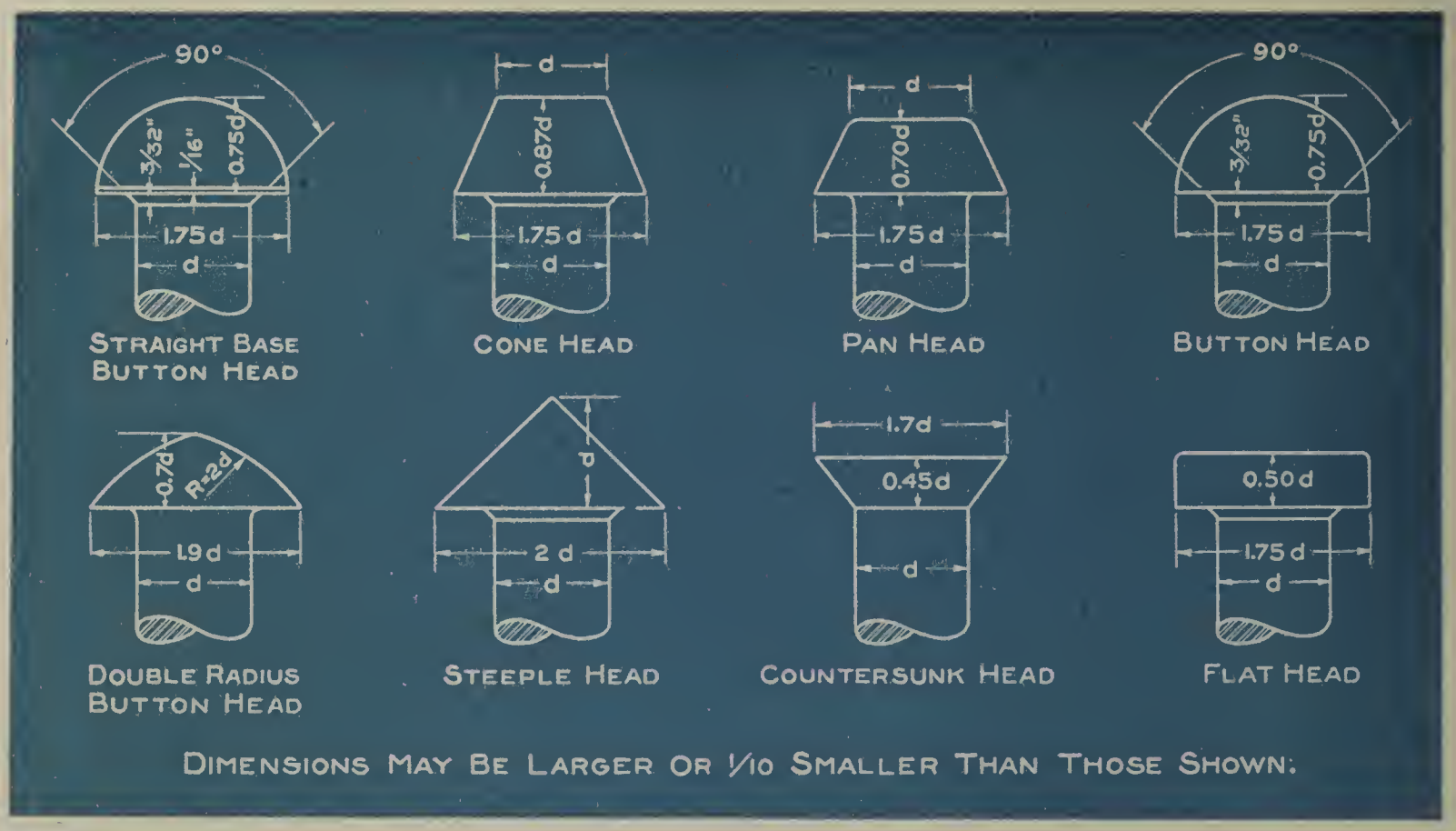
The cross-sectional area of rivets is taken as the area of the rivet holes, it being assumed that all rivets will be properly driven so as to entirely fill the holes.

All calculations are based on the use of steel rivets conforming to the requirements of the A. S. M. E. Boiler Code; no figures are given for iron rivets.

Allowable Shearing Strength of Steel Rivets.

Diameter of Rivet After Driving	Cross-Sectional Area of Rivet After Driving	Shearing Strength	
		Single Shear	Double Shear
11/16″—0.6875″	0.37122 sq. in.	16334 lbs.	32668 lbs.
3/4″—0.7500″	0.44179 " "	19439 "	38878 "
13/16″—0.8125″	0.51849 " "	22814 "	45628 "
7/8″—0.8750″	0.60132 " "	26458 "	52916 "
15/16″—0.9375″	0.69029 " "	30373 "	60746 "
1″ —1.0000″	0.78540 " "	34558 "	69116 "
1 1/16″—1.0625″	0.88664 " "	39012 "	78024 "
1 3/16″—1.1875″	1.1075 " "	48730 "	97460 "
1 5/16″—1.3125″	1.3530 " "	59532 "	119064 "
1 7/16″—1.4375″	1.6230 " "	71412 "	142824 "

STANDARD PROPORTIONS FOR RIVET HEADS



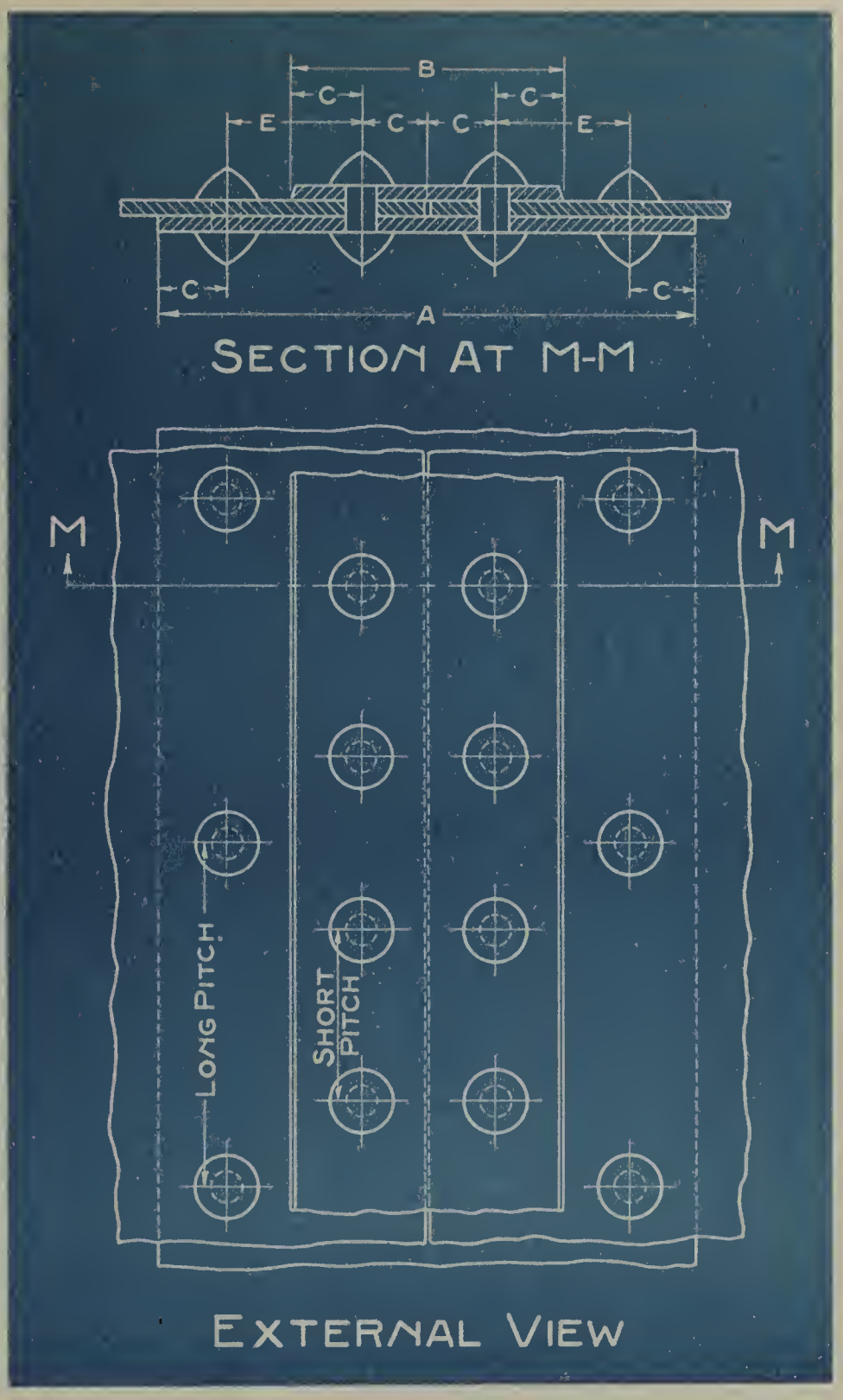
RIVETED JOINTS

Our designs for riveted joints have probably been copied and used more widely than any other data which we have issued. About four years ago we decided to make a complete new set of detail drawings for these joints because the tracings were getting worn so badly that it was impossible to make good blue prints from them. It seemed that this would be a good time to make any changes in design which might be desirable on account of variations in boiler-shop practices and customs, so we wrote to several boiler-makers, asking for copies of the tables which they were using and inviting suggestions for changes. In practically every case the boiler-maker returned a nearly exact copy of the standards which we had adopted years before and no suggestions were offered for any radical changes. In making the new drawings, however, we simplified the designs in some cases by eliminating some of the small fractions of an inch in pitch dimensions, and in some of the designs we had to increase the back-pitch slightly to comply with the requirements of the A. S. M. E. Boiler Code.

The tables which follow on Pages 7 to 13 show the various standard types of riveted joints with complete dimensions and with efficiencies computed in accordance with our usual practice as outlined on Page 5. Detail drawings are available for all of the butt-joint designs.

Designs are included for lap-joints though we seldom use this style of joint for longitudinal seams except in the cases of small vessels or vessels which will not be subjected to heat. Special designs will be found on Pages 14 and 15 for lap-joints to be used in circumferential seams.

DOUBLE-RIVETED BUTT-JOINTS



Typical Details of Design.

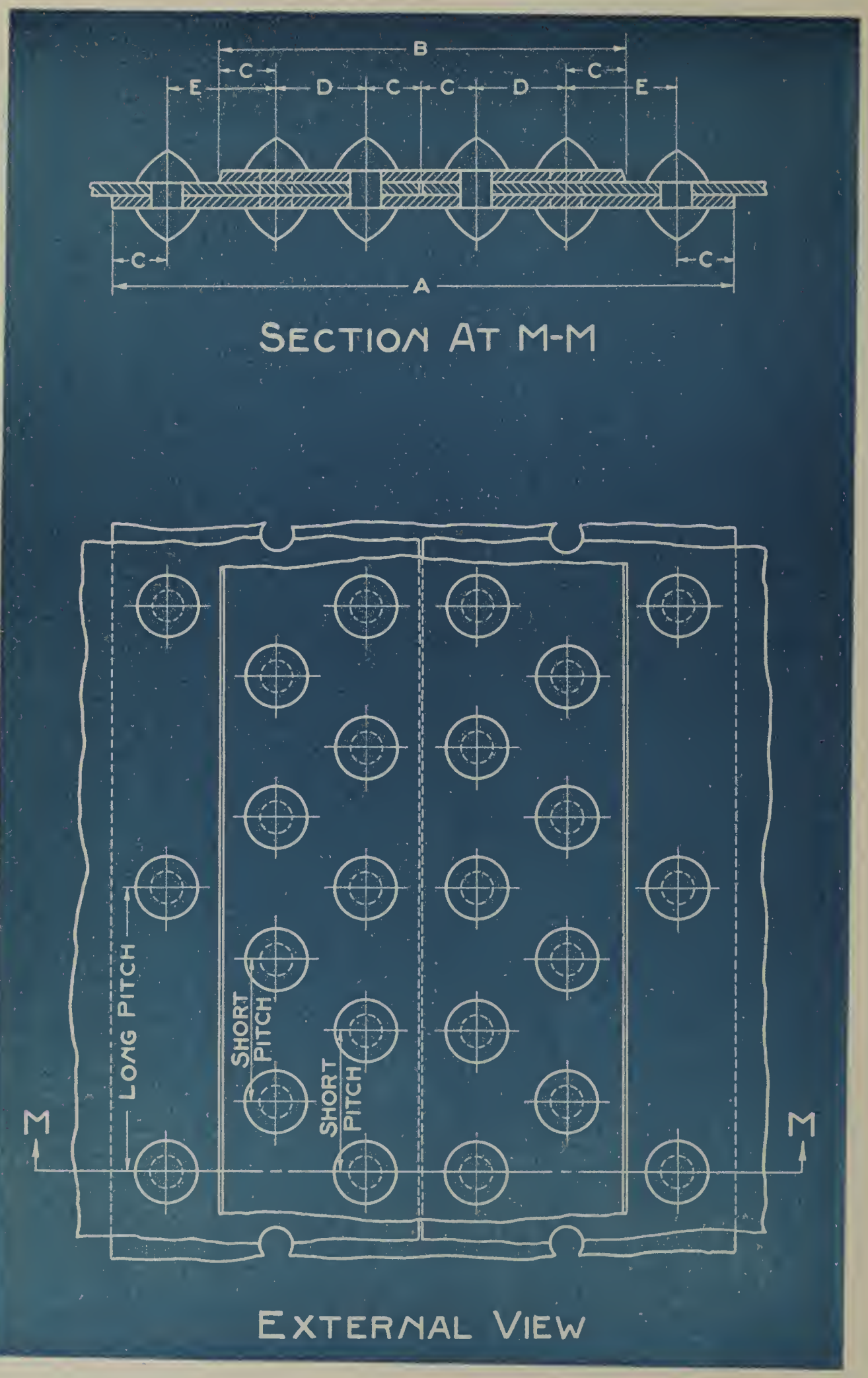
(See table below for dimensions, efficiencies, etc.)

Thickness of Plate	Thickness of Straps	Diameter of Rivet Hole	Efficiency %	Long Pitch	Short Pitch	A	B	C	E
1/4″	1/4″	11/16″	82.8	4″	2″	8 1/2″	4 1/4″	1 1/16″	2 1/8″
9/32″	1/4″	11/16″	82.8	4″	2″	8 1/2″	4 1/4″	1 1/16″	2 1/8″
5/16″	9/32″	13/16″	81.9	4 1/2″	2 1/4″	9 7/8″	5″	1 1/4″	2 7/16″
11/32″	9/32″	13/16″	81.9	4 1/2″	2 1/4″	9 7/8″	5″	1 1/4″	2 7/16″
3/8″	5/16″	13/16″	81.9	4 1/2″	2 1/4″	9 7/8″	5″	1 1/4″	2 7/16″
13/32″	5/16″	13/16″	81.9	4 1/2″	2 1/4″	9 7/8″	5″	1 1/4″	2 7/16″
7/16″	3/8″	15/16″	81.3	5″	2 1/2″	11 1/4″	5 3/4″	1 7/16″	2 3/4″
15/32″	3/8″	15/16″	81.3	5″	2 1/2″	11 1/4″	5 3/4″	1 7/16″	2 3/4″
1/2″	7/16″	15/16″	81.3	5″	2 1/2″	11 1/4″	5 3/4″	1 7/16″	2 3/4″

NOTE—All joints in the above table fail by tearing the plate between rivet holes in the outer row.

For convenience in driving rivets the back-pitch (dimension E) may be increased, if desired, without affecting the joint efficiency, but it should not be decreased.

TRIPLE-RIVETED BUTT-JOINTS



Typical Details of Design

For dimensions, efficiencies, etc., see table on opposite page.

TRIPLE-RIVETED BUTT-JOINTS

Table of Dimensions and Efficiencies

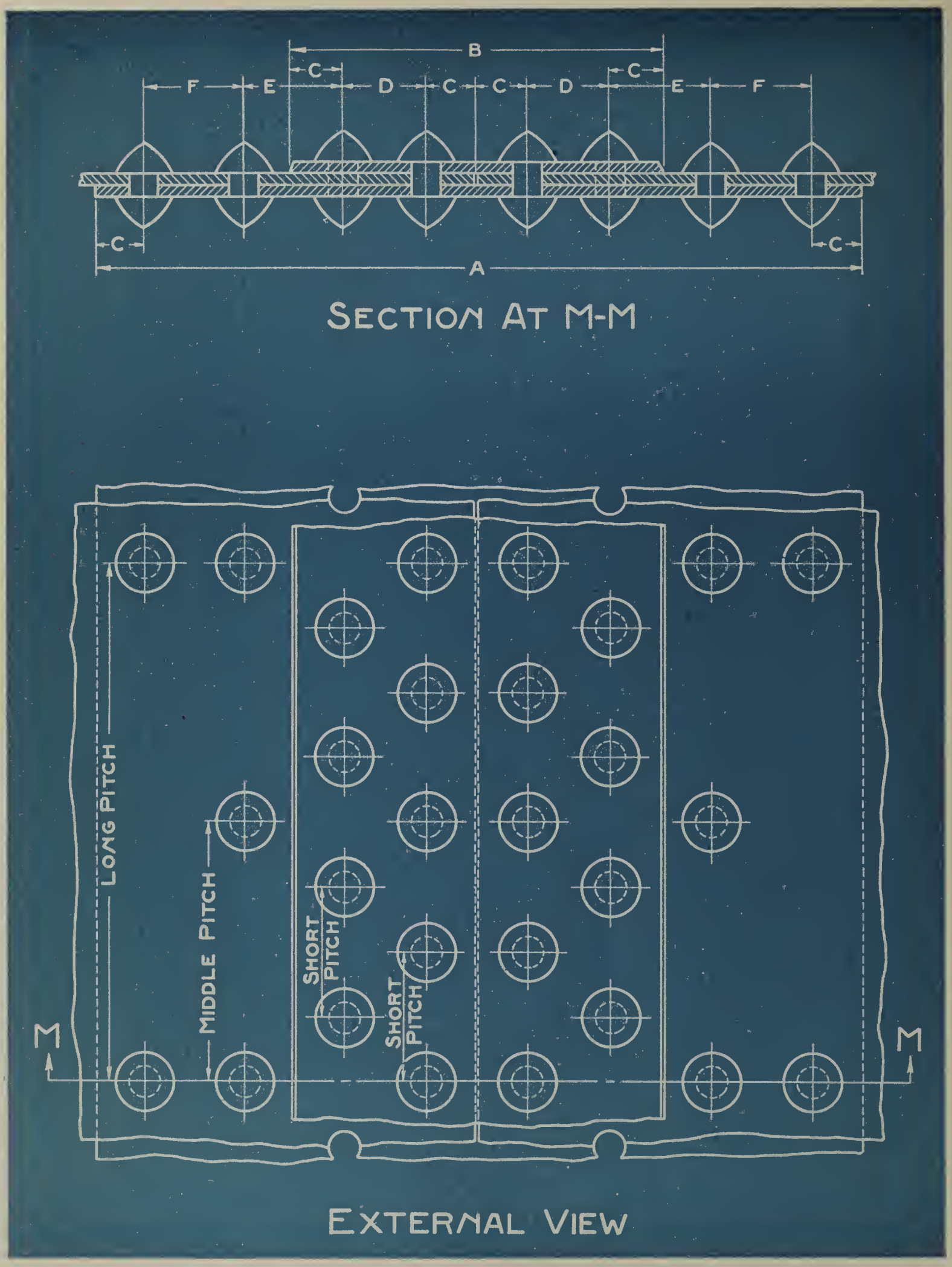
(Letters refer to sketch on opposite page.)

Thickness of Plate	Thickness of Straps	Diameter of Rivet Hole	Efficiency %	Long Pitch	Short Pitch	A	B	C	D	E
1/4″	1/4″	11/16″	87.5	5 1/2″	2 3/4″	12″	7 3/4″	1 1/16″	1 3/4″	2 1/8″
9/32″	1/4″	11/16″	87.5	5 1/2″	2 3/4″	12″	7 3/4″	1 1/16″	1 3/4″	2 1/8″
5/16″	5/32″	13/16″	87.5	6 1/2″	3 1/4″	13 5/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″
11/32″	5/32″	13/16″	87.5	6 1/2″	3 1/4″	13 5/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″
3/8″	5/16″	13/16″	88.4	7″	3 1/2″	13 5/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″
13/32″	5/16″	13/16″	88.4	7″	3 1/2″	13 5/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″
7/16″	3/8″	15/16″	87.9	7 3/4″	3 7/8″	15 1/4″	9 3/4″	1 7/16″	2″	2 3/4″
15/32″	3/8″	15/16″	87.9	7 3/4″	3 7/8″	15 1/4″	9 3/4″	1 7/16″	2″	2 3/4″
1/2″	7/16″	15/16″	88.3	8″	4″	15 1/4″	9 3/4″	1 7/16″	2″	2 3/4″
17/32″	7/16″	15/16″	88.3	8″	4″	15 1/4″	9 3/4″	1 7/16″	2″	2 3/4″
9/16″	7/16″	1 1/16″	86.7	8″	4″	17″	11″	1 5/8″	2 1/4″	3″
19/32″	1/2″	1 1/16″	86.7	8″	4″	17″	11″	1 5/8″	2 1/4″	3″
5/8″	1/2″	1 1/16″	86.7	8″	4″	17″	11″	1 5/8″	2 1/4″	3″
21/32″	1/2″	1 1/16″	86.7	8″	4″	17″	11″	1 5/8″	2 1/4″	3″
11/16″	1/2″	1 3/16″	85.6	8 1/4″	4 1/8″	18 1/2″	12″	1 13/16″	2 3/8″	3 1/4″
23/32″	1/2″	1 3/16″	85.6	8 1/4″	4 1/8″	18 1/2″	12″	1 13/16″	2 3/8″	3 1/4″
3/4″	1/2″	1 3/16″	85.5	8 1/4″	4 1/8″	18 1/2″	12″	1 13/16″	2 3/8″	3 1/4″
25/32″	9/16″	1 5/16″	84.6	8 1/2″	4 1/4″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
13/16″	9/16″	1 5/16″	84.6	8 1/2″	4 1/4″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
27/32″	9/16″	1 5/16″	84.2	8 1/2″	4 1/4″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
7/8″	5/8″	1 5/16″	84.1	8 3/4″	4 3/8″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
29/32″	5/8″	1 5/16″	83.6	8 3/4″	4 3/8″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
15/16″	11/16″	1 5/16″	83.7	9″	4 1/2″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
31/32″	11/16″	1 5/16″	83.2	9″	4 1/2″	20 1/4″	13 1/4″	2″	2 5/8″	3 1/2″
1″	3/4″	1 7/16″	83.4	9 1/2″	4 3/4″	22″	14 1/2″	2 3/16″	2 7/8″	3 3/4″

NOTE—Joints for plate thicknesses from 27/32″ to 1″ (both inclusive) fail by tearing the plate between rivet holes in the second row and shearing a rivet in the outer row; this also applies to the joint for the 3/4″ plate. All other joints in the above table fail by tearing the plate between rivet holes in the outer row.

For convenience in driving rivets, either of the dimensions for back-pitch (D and E) may be increased without affecting the joint efficiency, but they should not be decreased.

QUADRUPLE-RIVETED BUTT-JOINTS



Typical Details of Design

For dimensions, efficiencies, etc., see table on opposite page.

QUADRUPLE-RIVETED BUTT-JOINTS

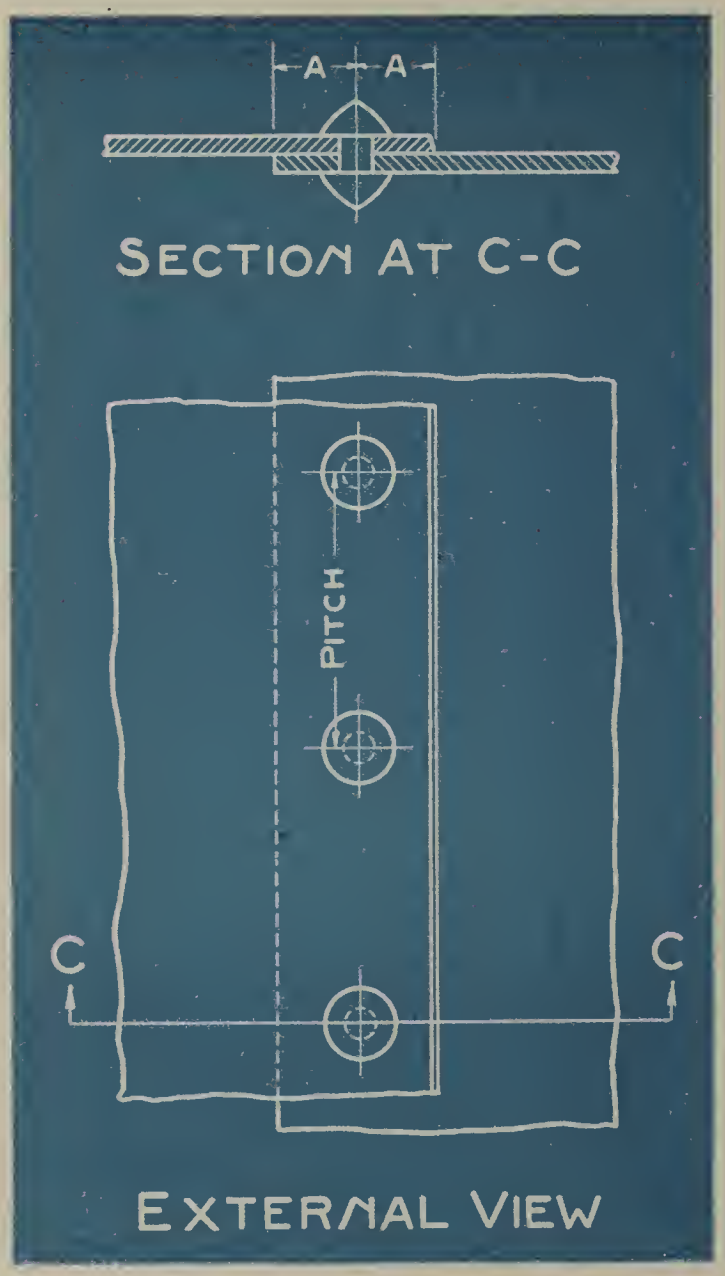
Table of Dimensions and Efficiencies

Thickness of Plate	Thickness of Straps	Diam. of Rivet Hole	Efficiency %	Long Pitch	Middle Pitch	Short Pitch	A	B	C	D	E	F
1/4"	1/4"	11/16"	93.8	11"	5 1/2"	2 3/4"	16 1/2"	7 3/4"	1 1/16"	1 3/4"	2 1/8"	2 1/4"
9/32"	1/4"	11/16"	93.8	11"	5 1/2"	2 3/4"	16 1/2"	7 3/4"	1 1/16"	1 3/4"	2 1/8"	2 1/4"
5/16"	9/32"	13/16"	93.8	13"	6 1/2"	3 1/4"	18 7/8"	8 3/4"	1 1/4"	1 7/8"	2 7/16"	2 5/8"
11/32"	9/32"	13/16"	93.8	13"	6 1/2"	3 1/4"	18 7/8"	8 3/4"	1 1/4"	1 7/8"	2 7/16"	2 5/8"
3/8"	5/16"	13/16"	94.2	14"	7"	3 1/2"	19 1/8"	8 3/4"	1 1/4"	1 7/8"	2 7/16"	2 3/4"
13/32"	5/16"	13/16"	94.2	14"	7"	3 1/2"	19 1/8"	8 3/4"	1 1/4"	1 7/8"	2 7/16"	2 3/4"
7/16"	3/8"	15/16"	94.0	15 1/2"	7 3/4"	3 7/8"	21 3/8"	9 3/4"	1 7/16"	2"	2 3/4"	3 1/16"
15/32"	3/8"	15/16"	94.0	15 1/2"	7 3/4"	3 7/8"	21 3/8"	9 3/4"	1 7/16"	2"	2 3/4"	3 1/16"
1/2"	7/16"	15/16"	94.1	16"	8"	4"	21 1/2"	9 3/4"	1 7/16"	2"	2 3/4"	3 1/8"
17/32"	7/16"	15/16"	94.1	16"	8"	4"	21 1/2"	9 3/4"	1 7/16"	2"	2 3/4"	3 1/8"
9/16"	7/16"	15/16"	94.1	16"	8"	4"	21 1/2"	9 3/4"	1 7/16"	2"	2 3/4"	3 1/8"
19/32"	1/2"	1 1/16"	93.4	16"	8"	4"	23 5/8"	11"	1 5/8"	2 1/4"	3"	3 5/16"
5/8"	1/2"	1 1/16"	93.4	16"	8"	4"	23 5/8"	11"	1 5/8"	2 1/4"	3"	3 5/16"
21/32"	1/2"	1 1/16"	93.4	16"	8"	4"	23 5/8"	11"	1 5/8"	2 1/4"	3"	3 5/16"
11/16"	1/2"	1 3/16"	92.8	16 1/2"	8 1/4"	4 1/8"	25 5/8"	12"	1 13/16"	2 3/8"	3 1/4"	3 9/16"
23/32"	1/2"	1 3/16"	92.8	16 1/2"	8 1/4"	4 1/8"	25 5/8"	12"	1 13/16"	2 3/8"	3 1/4"	3 9/16"
3/4"	1/2"	1 3/16"	92.7	16 1/2"	8 1/4"	4 1/8"	25 5/8"	12"	1 13/16"	2 3/8"	3 1/4"	3 9/16"
25/32"	9/16"	1 5/16"	92.3	17"	8 1/2"	4 1/4"	27 7/8"	13 1/4"	2"	2 5/8"	3 1/2"	3 13/16"
13/16"	9/16"	1 5/16"	92.3	17"	8 1/2"	4 1/4"	27 7/8"	13 1/4"	2"	2 5/8"	3 1/2"	3 13/16"
27/32"	9/16"	1 5/16"	91.8	17"	8 1/2"	4 1/4"	27 7/8"	13 1/4"	2"	2 5/8"	3 1/2"	3 13/16"
7/8"	5/8"	1 5/16"	91.2	17 1/2"	8 3/4"	4 3/8"	28"	13 1/4"	2"	2 5/8"	3 1/2"	3 7/8"
29/32"	5/8"	1 5/16"	90.5	17 1/2"	8 3/4"	4 3/8"	28"	13 1/4"	2"	2 5/8"	3 1/2"	3 7/8"
15/16"	11/16"	1 5/16"	90.1	18"	9"	4 1/2"	28 1/8"	13 1/4"	2"	2 5/8"	3 1/2"	3 15/16"
31/32"	11/16"	1 5/16"	89.5	18"	9"	4 1/2"	28 1/8"	13 1/4"	2"	2 5/8"	3 1/2"	3 15/16"
1"	3/4"	1 7/16"	90.2	19"	9 1/2"	4 3/4"	30 1/2"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 1/4"
1 1/32"	3/4"	1 7/16"	89.6	19"	9 1/2"	4 3/4"	30 1/2"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 1/4"
1 1/16"	3/4"	1 7/16"	89.0	19"	9 1/2"	4 3/4"	30 1/2"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 1/4"
1 3/32"	3/4"	1 7/16"	88.5	19"	9 1/2"	4 3/4"	30 1/2"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 1/4"
1 1/8"	3/4"	1 7/16"	88.0	19"	9 1/2"	4 3/4"	30 1/2"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 1/4"
1 5/32"	3/4"	1 7/16"	87.5	19"	9 1/2"	4 3/4"	30 1/2"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 1/4"
1 3/16"	13/16"	1 7/16"	87.7	20"	10"	5"	30 5/8"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 5/16"
1 7/32"	13/16"	1 7/16"	87.2	20"	10"	5"	30 5/8"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 5/16"
1 1/4"	7/8"	1 7/16"	86.8	20"	10"	5"	30 5/8"	14 1/2"	2 3/16"	2 7/8"	3 3/4"	4 5/16"

NOTE—Joints for plate thicknesses from 27/32" to 1 1/4" (both inclusive) fail by tearing the plate between rivet holes in the third row and shearing the rivets in the two outer rows; this also applies to the joint for the 3/4" plate. All other joints in the above table fail by tearing the plate between rivet holes in the outer row.

For convenience in driving rivets, any of the dimensions for back-pitch (dimensions D, E, and F) may be increased, if desired, without affecting the joint efficiency, but they should not be decreased.

SINGLE-RIVETED LAP-JOINTS



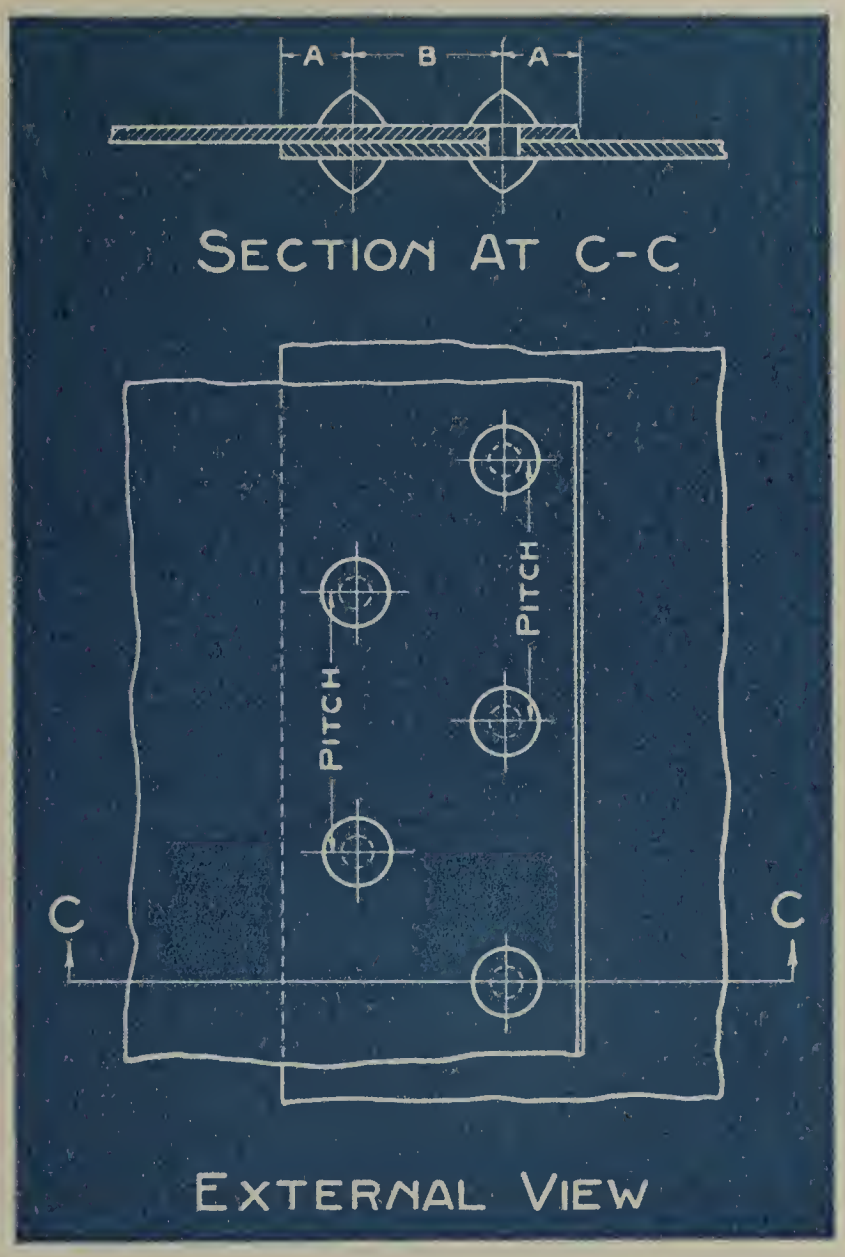
Typical Details of Design

(See table below for dimensions, efficiencies, etc.)

Thickness of Plate	Diameter of Rivet Holes	Efficiency %	Pitch	A	Method of Failure
1/4″	11/16″	60.7	1 3/4″	1 1/16″	T. P.
9/32″	11/16″	60.3	1 3/4″	1 1/16″	S. R.
5/16″	13/16″	59.4	2″	1 1/4″	T. P.
11/32″	13/16″	59.4	2″	1 1/4″	T. P.
3/8″	15/16″	58.3	2 1/4″	1 7/16″	T. P.
13/32″	15/16″	58.3	2 1/4″	1 7/16″	T. P.
7/16″	1 1/16″	57.5	2 1/2″	1 5/8″	T. P.
15/32″	1 1/16″	57.5	2 1/2″	1 5/8″	T. P.
1/2″	1 1/16″	56.7	2 1/2″	1 5/8″	S. R.

NOTE—In the column headed "Method of Failure," "T. P." indicates that the joint will fail by tearing the plate in the net section between rivet holes; "S. R." means that the failure will be due to shearing rivets.

DOUBLE-RIVETED LAP-JOINTS



Typical Details of Design

(See table below for dimensions, efficiencies, etc.)

Thickness of Plate	Diameter of Rivet Holes	Efficiency %	Pitch	A	B
1/4″	11/16″	69.5	2 1/4″	1 1/16″	1 3/4″
9/32″	11/16″	69.5	2 1/4″	1 1/16″	1 3/4″
5/16″	13/16″	69.1	2 5/8″	1 1/4″	1 7/8″
11/32″	13/16″	69.1	2 5/8″	1 1/4″	1 7/8″
3/8″	15/16″	68.9	3″	1 7/16″	2″
13/32″	15/16″	68.9	3″	1 7/16″	2″
7/16″	1 1/16″	68.5	3 3/8″	1 5/8″	2 1/8″
15/32″	1 1/16″	68.5	3 3/8″	1 5/8″	2 1/8″
1/2″	1 1/16″	68.5	3 3/8″	1 5/8″	2 1/8″

NOTE—All joints described by the above table will fail by tearing the plate in the net section between rivet holes.

LAP-RIVETED JOINTS FOR GIRTH SEAMS OF HORIZONTAL TUBULAR BOILERS

In cases like that usually found in horizontal tubular boilers where 50% or more of the load which would act on an unstayed solid head of the same diameter as the shell, is relieved by the effect of tubes or through stays, the strength of the circumferential joints in the shell should be at least 35% of that required for the longitudinal joints; and when such circumferential joints are exposed to the products of combustion, the shearing strength of the rivets should be not less than 50% of the full strength of the plate corresponding to the thickness at the joint. The following table of single-riveted lap-joints is designed to meet the above conditions, using rivets of the same size as those in our standard designs for butt-joints. We do not advise the use of plates thicker than 9/16" when the girth seams, under pressure, are exposed to the fire or products of combustion and the table is therefore not extended beyond this limit.

Thickness of Plate	Diameter of Rivet Holes	Pitch of Rivets	Efficiency of Joint	Shearing Strength of Rivets in per cent of Solid Plate
1/4"	11/16"	1 3/4"	60.7	67.9
9/32"	11/16"	1 3/4"	60.3	60.3
5/16"	13/16"	1 7/8"	56.7	70.8
11/32"	13/16"	1 7/8"	56.7	64.4
3/8"	13/16"	1 7/8"	56.7	59.1
13/32"	13/16"	1 7/8"	54.5	54.5
7/16"	15/16"	2 1/8"	55.9	59.4
15/32"	15/16"	2 1/8"	55.4	55.4
1/2"	15/16"	2 1/8"	52.0	52.0
17/32"	15/16"	2 1/16"	50.4	50.4
9/16"	1 1/16"	2 3/8"	53.3	53.3

In portions of girth seams which will be subjected to the hot fire, the riveting should be started at the bottom of the boiler and carried up continuously on both sides, reaming the holes anew as the seam is riveted up to the full diameter of the boiler.

LAP-RIVETED JOINTS FOR GIRTH SEAMS OF CYLINDRICAL VESSELS WITH SOLID UNSTAYED HEADS

In horizontal tubular boilers, tanks and similar vessels it is customary for the sake of convenience, to use the same size of rivets in the girth seams as in the longitudinal seams. Where the heads of such vessels are not stayed by tubes or through braces the strength of the circumferential joints should be at least 50% of that required for the longitudinal joints of the vessel. The joints in the table below are designed to meet the above requirements and it should be understood that a higher efficiency could be obtained in some instances by using a different size of rivets. It is assumed in each case that the efficiency of the corresponding longitudinal joint is not greater than that of our standard design for Quadrupled-Riveted Butt-Joints as shown on Page 11.

Thickness of Plate	Diameter of Rivet Holes	Single-Riveted Lap Joints		Double-Riveted Lap Joints	
		Pitch of Rivets	Efficiency of Joint	Pitch of Rivets	Efficiency of Joint
1/4"	11/16"	1 3/4"	60.7		
9/32"	11/16"	1 3/4"	60.3		
5/16"	13/16"	1 7/8"	56.7		
11/32"	13/16"	1 7/8"	56.7		
3/8"	13/16"	1 7/8"	56.7		
13/32"	13/16"	1 7/8"	54.5		
7/16"	15/16"	2 1/8"	55.9		
15/32"	15/16"	2 1/8"	55.4		
1/2"	15/16"	2 1/8"	52.0		
17/32"	15/16"	2 1/16"	50.4	3"	68.8
9/16"	1 1/16"	2 3/8"	53.3	3 1/4"	67.3
19/32"	1 1/16"			3 1/4"	67.3
5/8"	1 1/16"			3 1/4"	67.3
21/32"	1 1/16"			3 1/4"	66.5
11/16"	1 3/16"			3 3/4"	68.3
23/32"	1 3/16"			3 3/4"	65.8
3/4"	1 3/16"			3 3/4"	63.0
25/32"	1 5/16"			4"	67.2
13/16"	1 5/16"			4"	66.6
27/32"	1 5/16"			4"	64.1
7/8"	1 5/16"			4"	61.9
29/32"	1 5/16"			4"	59.7
15/16"	1 5/16"			4"	57.7
31/32"	1 5/16"			4"	55.9
1"	1 7/16"			4 1/2"	57.7
1 1/32"	1 7/16"			4 1/2"	56.0
1 1/16"	1 7/16"			4 1/2"	54.3
1 3/32"	1 7/16"			4 1/2"	52.8
1 1/8"	1 7/16"			4 1/2"	51.3
1 5/32"	1 7/16"			4 1/2"	49.9
1 3/16"	1 7/16"			4 1/2"	48.6
1 7/32"	1 7/16"			4 1/2"	47.4
1 1/4"	1 7/16"			4 1/2"	46.2

ALLOWABLE WORKING PRESSURES ON CYLINDRICAL SHELLS

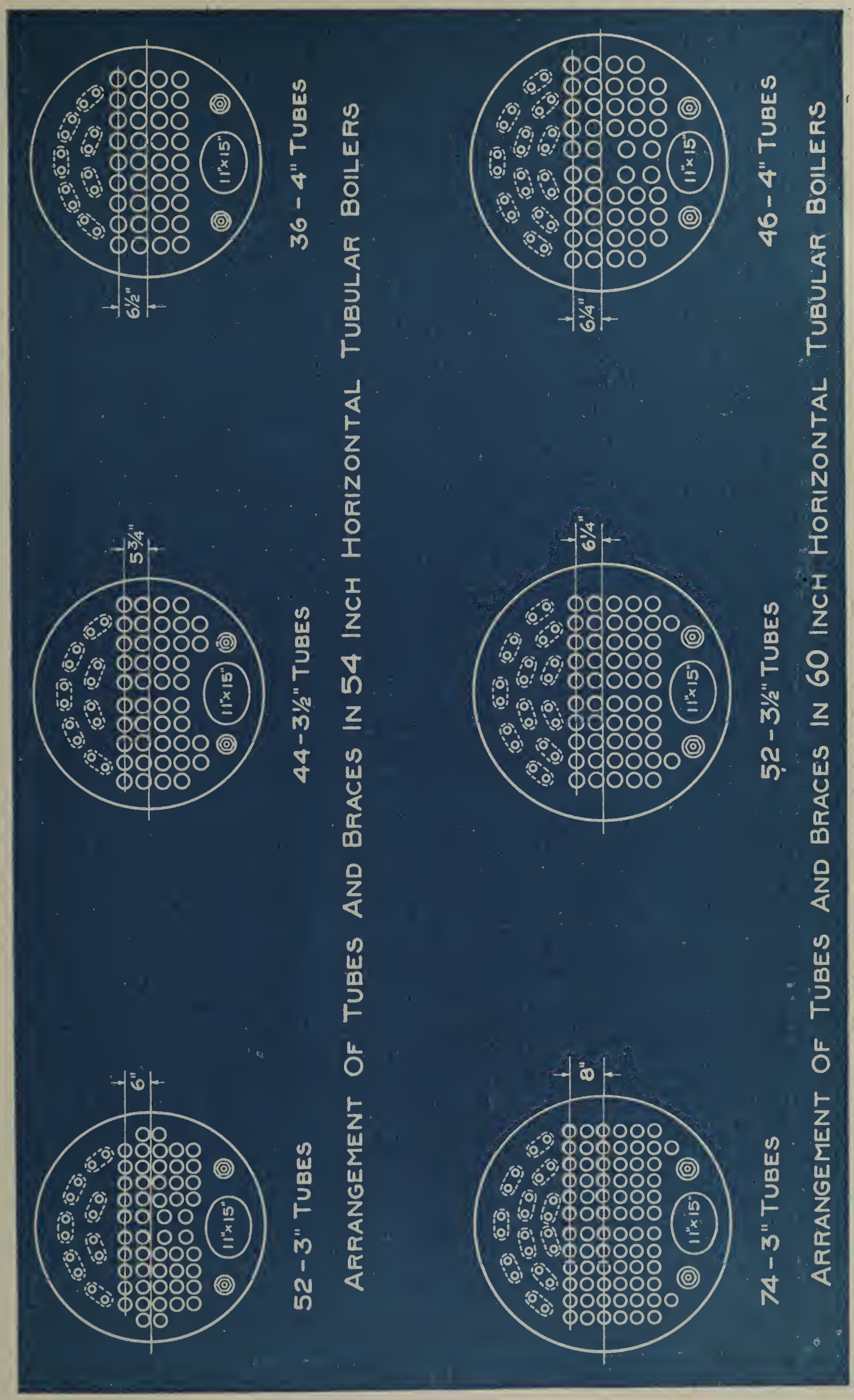
DIAMETER OF SHELL

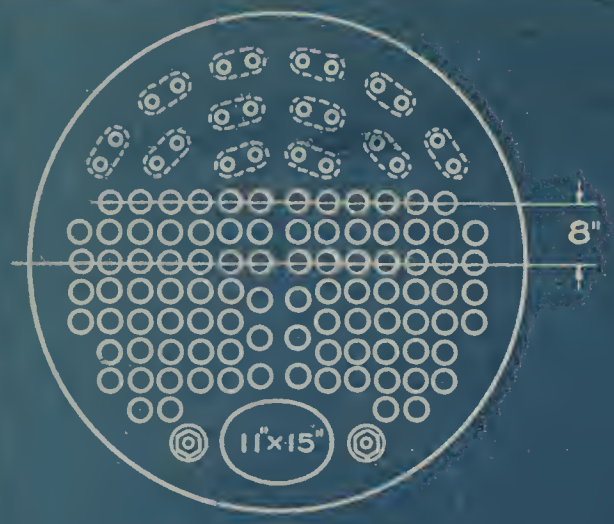
Plate Thickness	24″	30″	36″		42″		48″		54″		60″			66″			72″			78″		84″		90″	96″	102″	108″
	Dbl. Rvt.	Dbl. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Qd. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Qd. Rvt.	Dbl. Rvt.	Tpl. Rvt.	Qd. Rvt.	Tpl. Rvt.	Qd. Rvt.	Tpl. Rvt.	Qd. Rvt.	Qd. Rvt.	Qd. Rvt.	Qd. Rvt.	Qd. Rvt.
1/4″	189.7	151.8	126.5	133.6	108.4	114.5	94.8	100.2	84.3	89.1	75.8	80.2	85.9	68.9	72.9	78.1	63.2	66.8	71.6	61.6	66.1	57.2	61.4	57.3	53.7	50.5	47.7
9/32″	213.4	170.7	142.3	150.3	121.9	128.9	106.7	112.7	94.8	100.2	85.3	90.2	96.7	77.6	82.0	87.9	71.1	75.1	80.6	69.4	74.4	64.4	69.0	64.4	60.4	56.8	53.7
5/16″	234.6	187.6	156.4	167.1	134.0	143.2	117.3	125.3	104.2	111.4	93.8	100.2	107.4	85.3	91.1	97.7	78.2	83.5	89.5	77.1	82.6	71.6	76.7	71.6	67.1	63.2	59.7
11/32″	258.0	206.4	172.0	183.8	147.4	157.5	129.0	137.8	114.6	122.5	103.2	110.2	118.2	93.8	100.2	107.4	86.0	91.9	98.5	84.8	90.9	78.7	84.4	78.8	73.8	69.5	65.6
3/8″	281.5	225.2	187.6	202.5	160.8	173.6	140.7	151.9	125.1	135.0	112.6	121.5	129.5	102.3	110.5	117.7	93.8	101.2	107.9	93.5	99.6	86.8	92.5	86.3	80.9	76.1	71.9
13/32″	304.9	243.9	203.3	219.4	174.2	188.1	152.4	164.5	135.5	146.2	121.9	131.6	140.3	110.9	119.7	127.5	101.6	109.7	116.9	101.2	107.9	94.0	100.2	93.5	87.6	82.5	77.9
7/16″	326.0	260.8	217.3	235.0	186.3	201.4	163.0	176.2	144.9	156.6	130.4	141.0	150.7	118.5	128.1	137.0	108.6	117.5	125.5	108.4	115.9	100.7	107.7	100.5	94.2	88.7	83.7
15/32″	349.3	279.4	232.8	251.7	199.6	215.8	174.6	188.8	155.2	167.8	139.7	151.0	161.5	127.0	137.3	146.8	116.4	125.8	134.6	116.2	124.2	107.9	115.3	107.7	100.9	95.0	89.7
1/2″	372.6	298.1	248.4	269.8	212.9	231.2	186.3	202.3	165.6	179.8	149.0	161.8	172.5	135.5	147.1	156.8	124.2	134.9	143.7	124.5	132.7	115.6	123.2	115.0	107.8	101.4	95.8
17/32″				286.6		245.7		215.0		191.1		172.0	183.2		156.3	166.6		143.3	152.7	132.2	140.9	122.8	130.9	122.1	114.5	107.8	101.8
9/16″				298.0		255.4		223.5		198.6		178.8	192.6		162.5	175.1		149.0	160.5	137.5	148.1	127.7	137.5	128.4	120.3	113.3	107.0
19/32″				314.5		269.6		235.9		209.7		188.7	203.3		171.6	184.8		157.2	169.4	145.1	156.4	134.8	145.2	135.6	127.1	119.6	112.9
5/8″				331.1		283.8		248.3		220.7		198.6	214.0		180.6	194.5		165.5	178.3	152.8	164.6	141.9	152.8	142.6	133.7	125.9	118.9
21/32″				347.7		298.0		260.7		231.8		208.6	224.7		189.6	204.3		173.8	187.2	160.4	172.8	149.0	160.5	149.8	140.4	132.2	124.8
11/16″				359.6		308.2		269.7		239.7		215.7	233.9		196.1	212.6		179.8	194.9	165.9	179.9	154.1	167.0	155.9	146.2	137.6	129.9
23/32″				375.9		322.2		281.9		250.6		225.5	244.5		205.0	222.3		187.9	203.8	173.4	188.1	161.1	174.6	163.0	152.8	143.8	135.8
3/4″				391.8		335.8		293.9		261.2		235.1	254.9		213.7	231.7		195.9	212.4	180.8	196.0	167.9	182.0	169.9	159.3	149.9	141.6
25/32″				403.9		346.2		302.9		269.2		242.3	264.3		220.3	240.3		201.9	220.3	186.4	203.3	173.1	188.8	176.2	165.2	155.5	146.8
13/16″				420.0		360.0		315.0		280.0		252.0	274.9		229.1	249.9		210.0	229.1	193.8	211.5	180.0	196.4	183.3	171.8	161.7	152.7
27/32″				434.1		372.1		325.5		289.4		260.4	284.0		236.7	258.1		217.0	236.6	200.3	218.4	186.0	202.8	189.3	177.5	167.0	157.7
7/8″				449.7		385.4		337.2		299.8		269.8	292.6		245.2	266.0		224.8	243.8	207.5	225.0	192.7	209.0	195.0	182.8	172.1	162.5
29/32″				462.9		396.8		347.2		308.6		277.7	300.7		252.5	273.3		231.4	250.6	213.6	231.3	198.4	214.8	200.4	187.9	176.8	167.0
15/16″				479.5		411.0		359.6		319.6		287.7	309.7		261.5	281.5		239.7	258.0	221.3	238.2	205.5	221.2	206.4	193.5	182.1	172.0
31/32″				492.5		422.1		369.4		328.3		295.5	317.9		268.6	289.0		246.2	264.9	227.3	244.5	211.0	227.0	211.9	198.6	187.0	176.6
1″				509.6		436.8		382.2		339.7		305.8	330.7		278.0	300.6		254.8	275.6	235.2	254.4	218.4	236.2	220.4	206.7	194.5	183.7
1 1/32″													338.8			308.0			282.3		260.6		242.0	225.8	211.7	199.2	188.2
1 1/16″													346.7			315.2			288.9		266.7		247.6	231.1	216.7	203.9	192.6
1 3/32″													354.9			322.6			295.7		273.0		253.5	236.6	221.8	208.7	197.1
1 1/8″													363.0			330.0			302.5		279.2		259.2	242.0	226.8	213.5	201.6
1 5/32″													370.9			337.2			309.1		285.3		264.9	247.3	231.8	218.2	206.0
1 3/16″													381.8			347.1			318.2		293.7		272.7	254.5	238.6	224.6	212.1
1 7/32″													389.6			354.2			324.7		299.7		278.3	259.7	243.5	229.2	216.4
1 1/4″													397.8			361.6			331.5		306.0		284.1	265.2	248.6	234.0	221.0

NOTE—The above table is based on the use of butt-joints with efficiencies as shown on Pages 7, 9 and 11. See Page 5 also. The formula for working pressure is

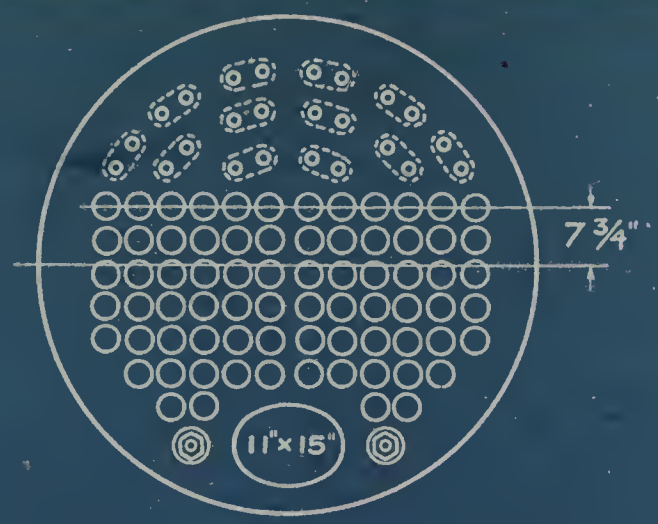
$$P = \frac{t \times T.S. \times E}{R \times F.S.}$$

where P = maximum allowable working pressure, lbs. per sq. in.
t = minimum thickness of shell plates in weakest course, inches.
T.S. = ultimate tensile strength of steel in shell plates, lbs. per sq. in.
E = efficiency of longitudinal joint (or of ligaments between tube holes.)
R = inside radius of weakest course of the shell, inches.
F.S. = factor of safety.

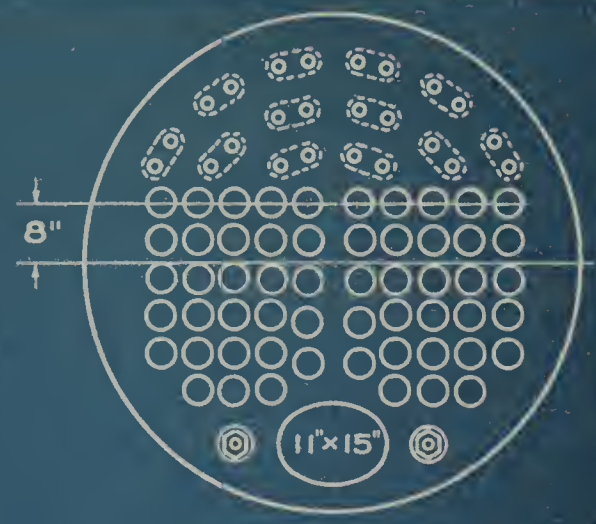

ARRANGEMENT OF TUBES AND BRACES IN 54 INCH HORIZONTAL TUBULAR BOILERS
36-4" TUBES
6½"
11"×15"
46-4" TUBES
6¼"
11"×15"
44-3½" TUBES
5¾"
11"×15"
52-3½" TUBES
6¼"
11"×15"
52-3" TUBES
6"
11"×15"
74-3" TUBES
8"
11"×15"
ARRANGEMENT OF TUBES AND BRACES IN 60 INCH H



94-3" Tubes

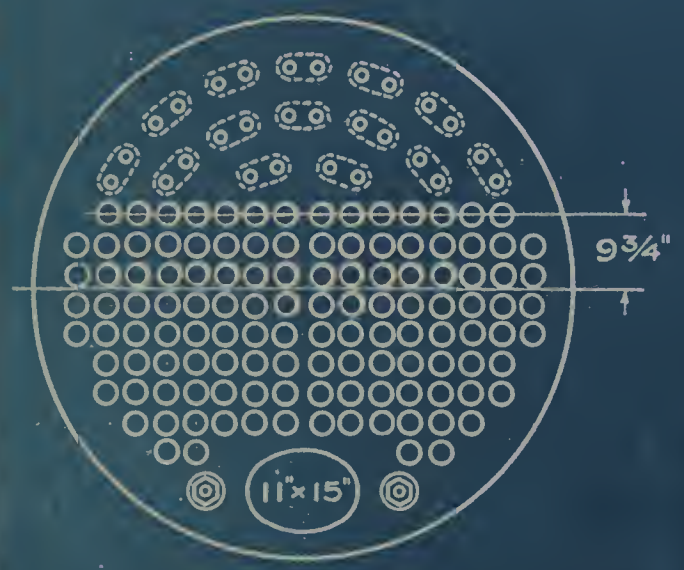


74-3½" Tubes

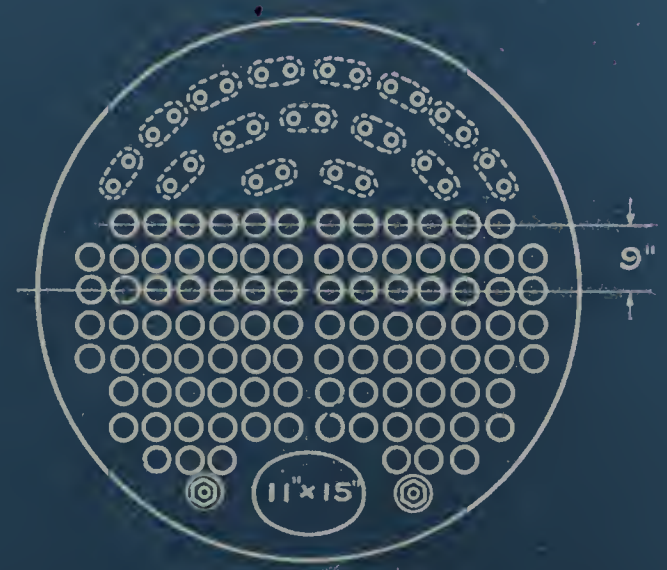


56-4" Tubes

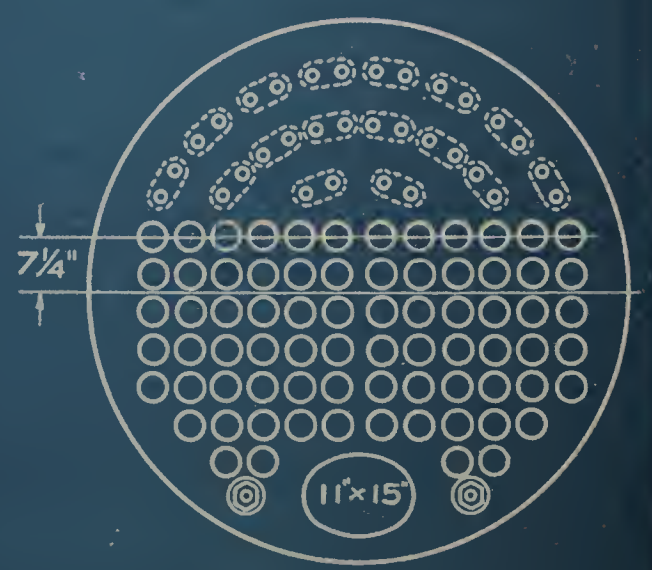
Arrangement Of Tubes And Braces In 66 Inch Horizontal Tubular Boilers



122-3" Tubes

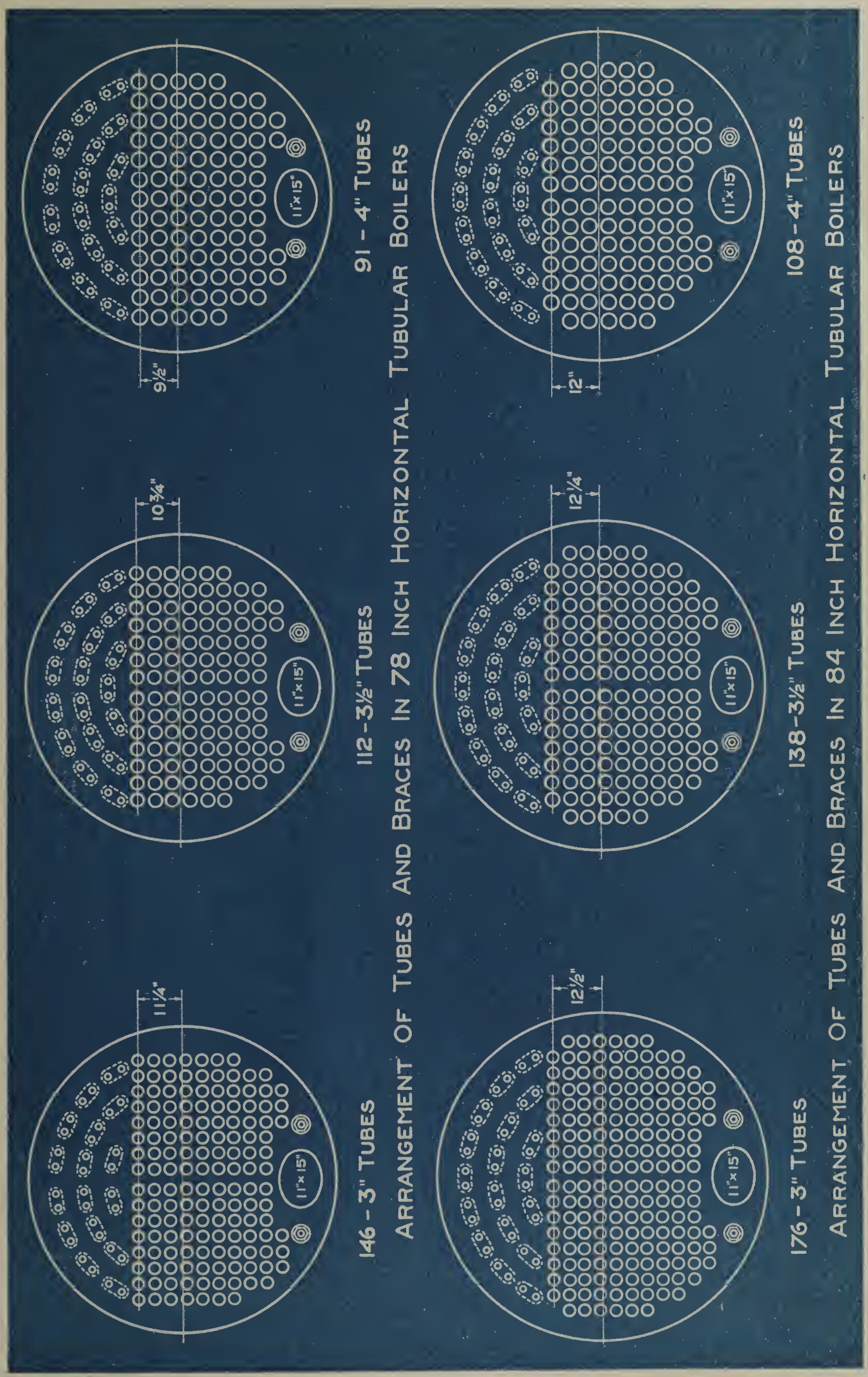


98-3½" Tubes

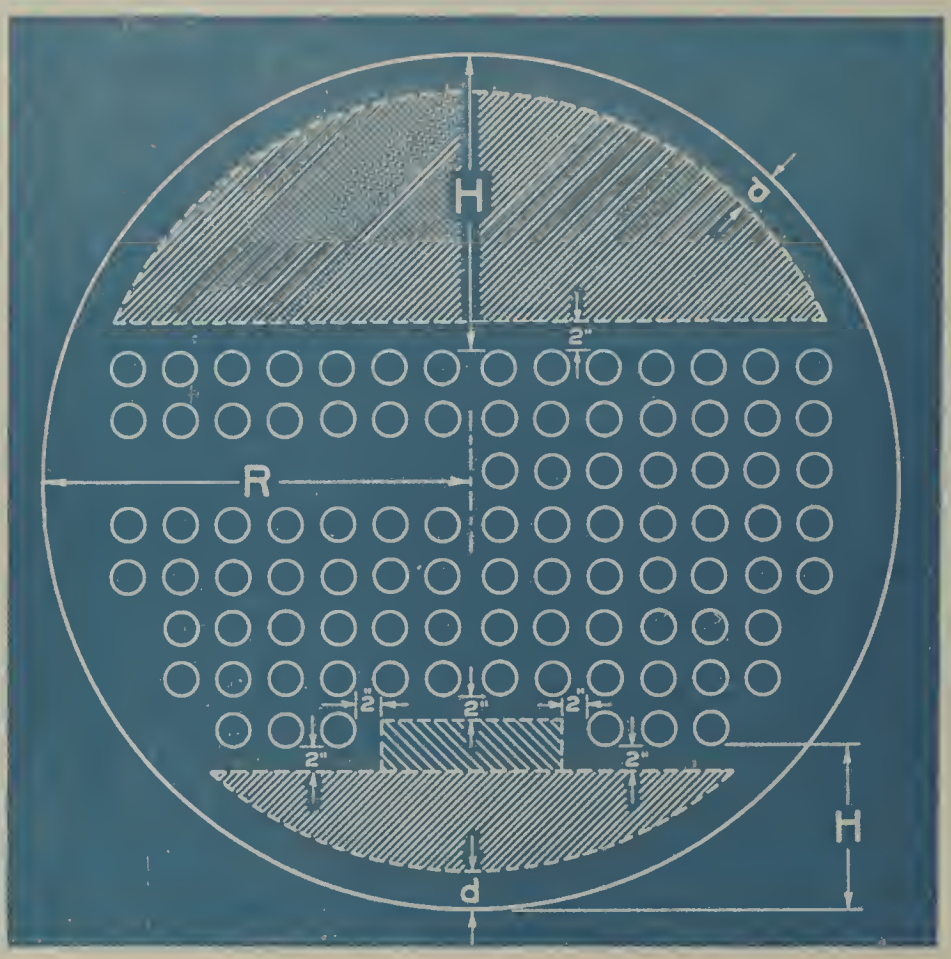


74-4" Tubes

Arrangement Of Tubes And Braces In 72 Inch Horizontal Tubular Boilers


ARRANGEMENT OF TUBES AND BRACES IN 78 INCH HORIZONTAL TUBULAR BOILERS
91 - 4" TUBES
9½"
11"×15"
108 - 4" TUBES
12"
11"×15"
112 - 3½" TUBES
10¾"
11"×15"
138 - 3½" TUBES
12¼"
11"×15"
146 - 3" TUBES
11¼"
11"×15"
176 - 3" TUBES
12½"
11"×15"

AREAS TO BE STAYED IN HEADS OF HORIZONTAL TUBULAR BOILERS



The diagram above shows a typical layout of tubes in the head of a horizontal tubular boiler, the areas which require bracing being indicated by shading. The distance of two inches (2″) from the tubes where bracing is not required is taken as a constant for all sizes of boilers, all pressures and all head thicknesses but the distance supported by the flange of the head (indicated by the letter d) is dependent upon the pressure and the thickness of the head in each case. Values of d may be determined from the following table which is based on the formula:

$$d = \frac{5 \times T}{\sqrt{P}}$$

where d = unstayed distance from shell in inches.

P = maximum allowable working pressure in pounds per sq. in.

T = number of sixteenths of an inch in head thickness (T = 8 for ½″ head, 9 for 9/16″ head, etc.)

AREAS TO BE STAYED IN HEADS OF HORIZONTAL TUBULAR BOILERS—(Continued)

Value of d or Distance Supported by Flange of Head

Wrkng Pres.—lbs. per sq. in.	Thickness of Head (Inches)										
	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1.0
50	4.24	4.95	5.66	6.36	7.07	7.78	8.49	9.19	9.90	10.61	11.31
60	3.87	4.52	5.16	5.81	6.46	7.10	7.75	8.39	9.04	9.68	10.33
70	3.59	4.18	4.78	5.38	5.98	6.57	7.17	7.77	8.37	8.96	9.56
80	3.35	3.91	4.47	5.03	5.59	6.15	6.71	7.27	7.83	8.39	8.94
90	3.16	3.69	4.22	4.74	5.27	5.80	6.33	6.85	7.38	7.91	8.43
100	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00
110	2.86	3.33	3.81	4.29	4.77	5.24	5.72	6.20	6.67	7.15	7.63
120	2.75	3.21	3.66	4.12	4.58	5.04	5.50	5.96	6.42	6.88	7.33
125	2.68	3.13	3.58	4.03	4.47	4.92	5.37	5.81	6.26	6.71	7.16
130	2.63	3.07	3.50	3.95	4.38	4.82	5.26	5.70	6.14	6.57	7.00
140	2.53	2.95	3.38	3.80	4.22	4.64	5.07	5.49	5.91	6.33	6.76
150	2.45	2.85	3.26	3.67	4.08	4.49	4.90	5.31	5.71	6.12	6.53
160	2.37	2.77	3.16	3.56	3.95	4.35	4.74	5.14	5.53	5.93	6.32
170	2.30	2.68	3.06	3.44	3.83	4.22	4.60	4.98	5.37	5.75	6.13
180	2.23	2.60	2.98	3.35	3.72	4.10	4.47	4.84	5.21	5.59	5.96
190	2.17	2.54	2.90	3.26	3.63	3.99	4.35	4.72	5.08	5.44	5.80
200	2.12	2.47	2.83	3.18	3.54	3.89	4.24	4.59	4.95	5.30	5.66

The outside radius of the flange of the head may be used for d if such radius is greater than the value given in the above table for the required pressure and thickness of head, except that the value obtained in this manner must not be greater than eight (8) times the thickness of the head.

Referring again to the diagram on Page 20, the area of the rectangle shown by the wide cross-hatching can be easily determined from its length and width and the area of either segment can be calculated from the formula

$$\text{Area} = \frac{4(\text{H-d-2})^2}{3}\sqrt{\frac{2(\text{R-d})}{(\text{H-d-2})} - 0.608}$$

where H = distance from top (or bottom) of tubes to shell in inches.

R = radius of the boiler head in inches.

d = unstayed distance from shell in inches.

Our Engineering Department can furnish blue-prints of a table giving areas of segments based on this formula for different values of the two terms (H-d-2) and (R-d) but the table is too large to print conveniently in a book of this size. On the following page, however, will be found a table giving areas of segments for cases where d (as defined above) is equal to three inches (3″). It will be found that the calculated value of d is usually greater than 3 inches and, in such cases, the areas given in the table will therefore be somewhat larger than actually required so that they will be on the safe side.

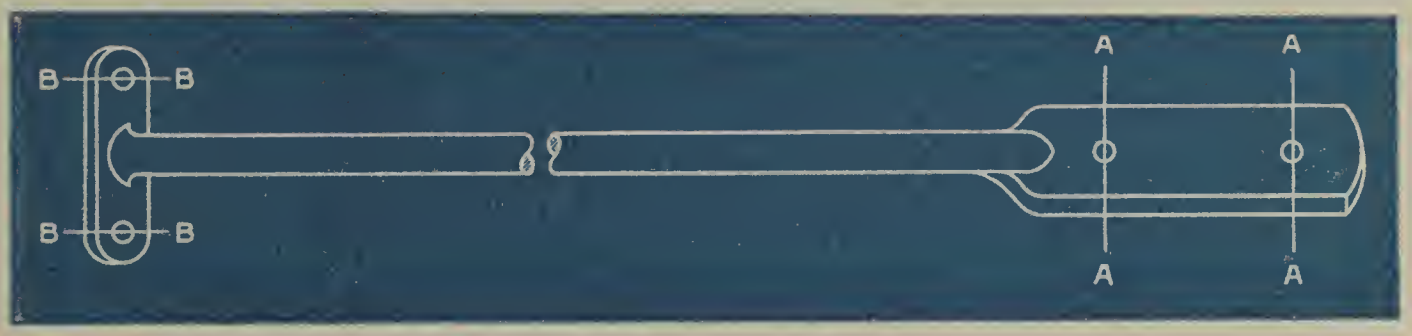
AREAS TO BE STAYED IN HEADS OF HORIZONTAL TUBULAR BOILERS—(Concluded)

Table Showing Net Areas of Segments of Heads Where d (as defined on Pages 20 and 21) is Equal to Three Inches (3″)

Height from Tubes to Shell, (Ins.)	Diameter of Boiler (Inches)												
	24	30	36	42	48	54	60	66	72	78	84	90	96
	Area to be stayed, Sq. In.												
8	28	33	37	40	43	47	51	53	55	58	60	63	65
8½	35	41	46	51	55	59	63	66	70	74	76	80	82
9	42	49	56	62	67	72	76	82	86	90	92	95	98
9½	50	58	66	70	80	86	91	96	101	105	111	116	119
10	57	68	77	85	93	99	106	112	117	123	129	132	137
10½	66	78	89	98	107	114	123	131	135	142	147	153	160
11	74	88	100	111	121	130	138	147	155	161	169	174	183
11½	83	99	112	124	137	146	156	165	173	181	189	196	204
12	91	109	125	139	151	163	174	184	194	203	213	219	230
12½	.....	120	138	153	167	180	193	204	216	224	234	243	252
13	.....	132	151	168	183	197	211	224	235	247	256	267	279
13½	.....	143	164	183	200	216	230	246	258	270	282	293	302
14	.....	155	178	199	217	234	250	266	280	294	305	319	331
14½	.....	167	192	215	235	254	271	287	303	318	333	345	360
15	.....	178	206	231	252	273	291	309	326	343	357	372	386
15½	.....	.....	220	247	271	291	312	332	350	368	382	400	417
16	.....	.....	235	263	289	312	334	355	374	394	411	423	443
16½	.....	.....	249	281	308	332	357	380	399	420	436	457	475
17	.....	.....	264	297	326	353	378	402	425	447	467	486	502
17½	.....	.....	.....	314	345	374	400	426	449	471	494	516	536
18	.....	.....	.....	331	365	396	424	450	476	500	520	543	564
18½	.....	.....	.....	349	384	417	448	476	501	526	552	577	598
19	.....	.....	.....	366	404	439	470	500	529	555	580	604	631
19½	.....	.....	.....	384	424	461	496	528	558	584	613	641	663
20	.....	.....	.....	401	444	483	519	552	583	613	642	667	699
20½	.....	.....	.....	.....	464	505	543	578	613	643	675	706	729
21	.....	.....	.....	.....	485	528	568	604	640	673	705	733	766
21½	.....	.....	.....	.....	505	551	594	632	669	703	739	766	797
22	.....	.....	.....	.....	526	574	618	658	697	734	769	800	835
22½	.....	.....	.....	.....	.....	597	643	687	726	765	800	835	867
23	.....	.....	.....	.....	.....	620	668	713	754	796	830	869	906
23½	.....	.....	.....	.....	.....	642	695	740	784	827	866	904	945
24	.....	.....	.....	.....	.....	667	719	768	814	859	897	939	978
24½	.....	.....	.....	.....	.....	689	745	797	843	892	934	975	1018
25	.....	.....	.....	.....	.....	714	771	825	875	922	966	1010	1051
25½	.....	.....	.....	.....	.....	737	798	855	907	956	1003	1047	1092
26	.....	.....	.....	.....	.....	761	824	882	936	987	1035	1083	1126
26½	.....	.....	.....	.....	.....	.....	850	909	968	1024	1073	1120	1167
27	.....	.....	.....	.....	.....	.....	877	939	998	1053	1106	1157	1202
27½	.....	.....	.....	.....	.....	.....	904	968	1030	1089	1145	1195	1243
28	.....	.....	.....	.....	.....	.....	930	997	1060	1120	1177	1232	1279
28½	.....	.....	.....	.....	.....	.....	.....	1028	1092	1157	1211	1270	1321
29	.....	.....	.....	.....	.....	.....	.....	1056	1123	1187	1248	1305	1360
29½	.....	.....	.....	.....	.....	.....	.....	1084	1155	1221	1284	1347	1400
30	.....	.....	.....	.....	.....	.....	.....	1115	1187	1255	1321	1382	1442
30½	.....	.....	.....	.....	.....	.....	.....	.....	1218	1290	1358	1424	1480
31	.....	.....	.....	.....	.....	.....	.....	.....	1252	1324	1394	1459	1523
31½	.....	.....	.....	.....	.....	.....	.....	.....	1286	1359	1433	1496	1561
32	.....	.....	.....	.....	.....	.....	.....	.....	1317	1394	1467	1538	1605
32½	.....	.....	.....	.....	.....	.....	.....	.....	.....	1430	1508	1575	1650
33	.....	.....	.....	.....	.....	.....	.....	.....	.....	1465	1542	1617	1687
33½	.....	.....	.....	.....	.....	.....	.....	.....	.....	1500	1578	1655	1733
34	.....	.....	.....	.....	.....	.....	.....	.....	.....	1536	1617	1695	1770
34½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1654	1735	1816
35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1692	1775	1856
35½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1810	1900
36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1857	1941
36½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1984
37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2026

PROPORTIONS OF DIAGONAL CROWFOOT STAYS

Diagonal crowfoot stays should be made of solid, weldless mild steel. Each branch of a crowfoot should be designed to carry two-thirds of the total load for which the stay is designed, the fulfilment of this requirement being proved by tests, if necessary. To develop the full strength of a stay, the combined cross-sectional area of the two rivets at each end should be at least one and one-quarter (1¼) times the cross-sectional area of the body of the stay. The net cross-sectional area through the center of each rivet hole in the blade of the stay should also be at least equal to one and one-quarter (1¼) times the cross-sectional area of the body of the stay, and the net area through the center of each rivet hole in the crowfoot should be at least one-half (½) of the net area through a rivet hole in the blade. The following table has been calculated to meet the above requirements.



Diameter of stay	Cross-sectional area of body of stay	Minimum Diam. of rivet holes	Minimum cross-sectional area at A-A	Minimum cross-sectional area at B-B
1⅛″	0.9940 sq. in.	15/16″	1.2425 sq. in.	0.6213 sq. in..
1 3/16″	1.1075 " "	1″	1.3844 " "	0.6922 " "
1¼″	1.2272 " "	1″	1.5340 " "	0.7670 " "

SPACING OF CROWFOOT STAYS

The number of crowfoot stays needed in any case is determined by spacing requirements as well as by the size of the area to be supported. In general the spacing should conform to the following requirements:

(1) The maximum spacing between the centers of rivets attaching the crowfeet of braces to the stayed surface should be determined by the value of p in the formula:

$$p = \sqrt{\frac{135T^2}{P}}$$

(2) The distance between the edges of tube holes and the centers of rivets attaching the crowfeet of braces to the stayed surface should not exceed the value of p in the above formula.

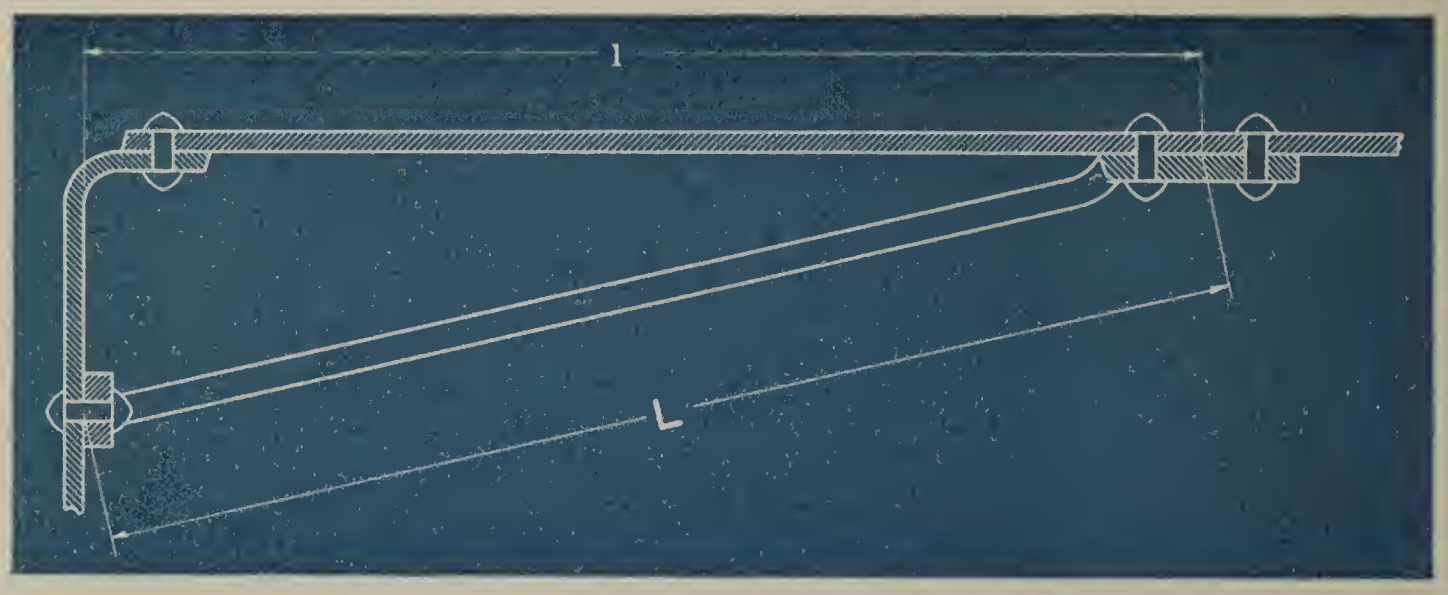
(3) The maximum spacing between the inner surface of the shell and lines parallel to the surface of the shell passing through the centers of rivets attaching the crowfeet of braces to the head should be determined by the value of p in the formula:

$$p = \sqrt{\frac{175T^2}{P}}$$

In the above formulae, P = maximum allowable working pressure, lbs. per sq. in.

T = the number of *sixteenths* of an inch in the thickness of the stayed surface. (T = 8 for ½″ plate, 9 for 9/16″ plate, etc.)

STRESSES IN DIAGONAL CROWFOOT STAYS AND AREAS SUPPORTED THEREBY



Because of the angularity of diagonal crowfoot stays with reference to the direction in which the load acts, greater cross-sectional areas are required than would be the case with direct stays. If a is the required area of a direct stay for any given conditions and A is the corresponding area for a diagonal stay, then

$$A:a = L:l \text{ or } A = \frac{a \times L}{l}$$

L and l being measured as indicated in the sketch above.

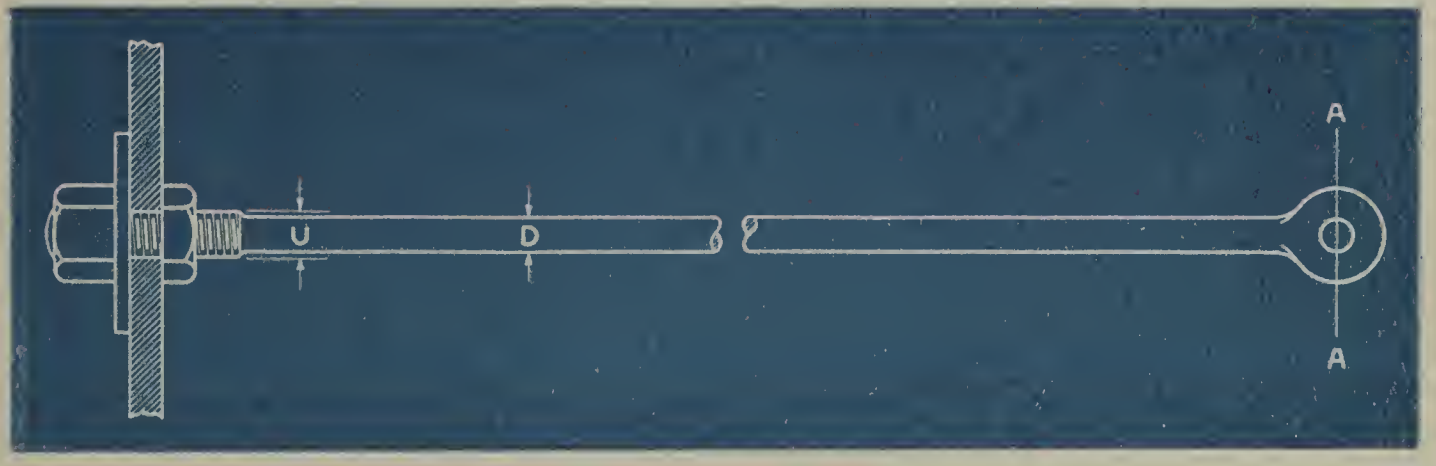
In horizontal tubular boilers L is usually not more than 1.15 times l and in such cases diagonal stays may be calculated as direct stays, allowing ninety per cent (90%) of the stress which would be permitted for such stays. For weldless mild steel direct stays not more than 120 diameters in length a stress of 9500 pounds per square inch is permissible so that the allowable stress for such diagonal stays would be 8550 pounds per square inch; this is usually taken as 8500 pounds for easy figuring. In any unusual case the relation of L to l should be checked and the required area should be figured from the formula given if L is greater than 1.15 times l. The following table has been calculated to show the maximum areas supported by the usual sizes of diagonal stays under various pressures. It is based on a stress of 8500 pounds per square inch which is equivalent to 8449 pounds for 1⅛ inch stays, 9414 pounds for 1^3⁄$_{16}$ inch stays and 10431 pounds for 1¼ inch stays.

Maximum Areas in Square Inches Supported by Weldless Mild Steel Diagonal Crowfoot Stays

Pressure Lbs. per sq. in.	Diameter of Stay			Pressure Lbs. per sq. in.	Diameter of Stay		
	1⅛″	1^3⁄$_{16}$″	1¼″		1⅛″	1^3⁄$_{16}$″	1¼″
100	84	94	104	180	46	52	58
105	80	89	99	185	45	50	56
110	76	85	94	190	44	49	54
115	73	81	90	195	43	48	53
120	70	78	87	200	42	47	52
125	67	75	83	210	40	44	49
130	65	72	80	220	38	42	47
135	62	69	77	230	36	40	45
140	60	67	74	240	35	39	43
145	58	64	72	250	33	37	41
150	56	62	69	260	32	36	40
155	54	60	67	270	31	34	38
160	52	58	65	280	30	33	37
165	51	57	63	290	29	32	36
170	49	55	61	300	28	31	34
175	48	53	59	310	27	30	33

PROPORTIONS OF THROUGH STAYS

Through stays should be upset on the threaded end so that the net cross-sectional area at the root of the thread will be at least equal to the cross-sectional area of the body of the stay. The diameter of the outside washer should be at least 2½ times the diameter of the stay; in certain cases a greater diameter will be necessary to meet spacing requirements. The eye on the opposite end of the stay should be made by upsetting and drilling a hole for the pin rather than by welding. To develop the full strength of a stay, the cross-sectional area of the pin should be at least three-fourths (¾) of the area through the body of the stay and the cross-sectional area through the center of the eye should be at least twenty-five per cent (25%) greater than the area through the body of the brace. The pin should be turned to make a neat fit in the hole. The combined cross-sectional area of the rivets attaching each stay to the head should be at least twenty-five per cent (25%) greater than the area through the body of the stay. The following table shows the proportions of weldless steel through stays necessary to meet the above requirements.



D Diameter of stay	Cross-sectional area of body. (sq. in.)	U Diameter of Upset*	Minimum diameter of Washer	Diameter of Pin	Minimum cross-sectional area at A-A (sq. in.)	Minimum combined area of rivets (sq. in.)
1″	0.7854	1¼″	2½″	⅞″	0.982	0.982
1⅛″	0.9940	1⅜″	2⅞″	1″	1.243	1.243
1¼″	1.2272	1½″	3⅛″	1⅛″	1.534	1.534
1⅜″	1.4849	1⅝″	3½″	1¼″	1.856	1.856
1½″	1.7672	1⅞″	3¾″	1⅜″	2.209	2.209
1⅝″	2.0739	2″	4⅛″	1½″	2.592	2.592
1¾″	2.4053	2¼″	4⅜″	1⅝″	3.007	3.007
1⅞″	2.7612	2¼″	4¾″	1⅝″	3.452	3.452
2″	3.1416	2½″	5″	1¾″	3.927	3.927
2⅛″	3.5466	2½″	5⅜″	1⅞″	4.433	4.433
2¼″	3.9761	2¾″	5⅝″	2″	4.970	4.970
2⅜″	4.4301	2¾″	6″	2⅛″	5.538	5.538
2½″	4.9087	3″	6¼″	2¼″	6.136	6.136

*Based on Sellers Standard Threads.

STRESSES IN THROUGH STAYS AND AREAS SUPPORTED THEREBY

For unwelded steel through-stays the allowable stresses should be figured in accordance with the following:

	Lengths not exceeding 120 diameters	Lengths exceeding 120 diameters
Diameters not exceeding 1½″	9500 lbs. per sq. in.	8500 lbs. per sq. in.
Diameters exceeding 1½″	10400 lbs. per sq. in.	9000 lbs. per sq. in.

On the above basis the following table has been prepared to show the maximum areas in square inches which can be supported by through stays of different diameters and lengths under varying pressures, it being assumed that the stays will be proportioned in accordance with the requirements stated on Page 25.

Maximum Areas in Square Inches Supported by Weldless Steel Through Stays

Pressure (Lbs. per sq. in.)	1⅛″ Diam.		1¼″ Diam.		1⅜″ Diam.		1½″ Diam.		1⅝″ Diam.	
	11′–3″ or less	Over 11′–3″	12′–6″ or less	Over 12′–6″	13′–9″ or less	Over 13′–9″	15′–0″ or less	Over 15′–0″	16′–3″ or less	Over 16′–3″
100	94	84	116	104	141	126	167	150	215	186
105	89	80	111	99	134	120	159	143	205	177
110	85	76	105	94	128	114	152	136	196	169
115	82	73	101	90	122	109	145	130	187	162
120	78	70	97	86	117	105	139	125	179	155
125	75	67	93	83	112	100	134	120	172	149
130	72	64	89	80	108	97	129	115	165	143
135	69	62	86	77	104	93	124	111	159	138
140	67	60	83	74	100	90	119	107	154	133
145	65	58	80	71	97	87	115	103	148	128
150	62	56	77	69	94	84	111	100	143	124
155	60	54	75	67	91	81	108	96	139	120
160	59	52	72	65	88	78	104	93	134	116
165	57	51	70	63	85	76	101	91	130	113
170	55	49	68	61	82	74	98	88	126	109
175	53	48	66	59	80	72	95	85	123	106
180	52	46	64	57	78	70	93	83	119	103
185	51	45	63	56	76	68	90	81	116	100
190	49	44	61	54	74	66	88	79	113	98
195	48	43	59	53	72	64	86	77	110	95
200	47	42	58	52	70	63	83	75	107	93
210	44	40	55	49	67	60	79	71	102	88
220	42	38	53	47	64	57	76	68	98	84
230	41	36	50	45	61	54	72	65	93	81
240	39	35	48	43	58	52	69	62	89	77
250	37	33	46	41	56	50	67	60	86	74
260	36	32	44	40	54	48	64	57	82	71
270	34	31	43	38	52	46	62	55	79	69
280	33	30	41	37	50	45	59	53	77	66
290	32	29	40	35	48	43	57	51	74	64
300	31	28	38	34	47	42	55	50	71	62

Maximum Areas in Square Inches Supported by Weldless Steel Through Stays (Concluded)

Pressure (Lbs. per sq. in.)	1¾″ Diam.		1⅞″ Diam.		2″ Diam.		2⅛″ Diam.		2¼″ Diam.	
	17′–6″ or less	Over 17′–6″	18′–9″ or less	Over 18′–9″	20′–0″ or less	Over 20′–0″	21′–3″ or less	Over 21′–3″	22′–6″ or less	Over 22′–6″
100	250	216	287	248	326	282	368	319	413	357
105	238	206	273	236	311	269	350	303	393	340
110	227	196	261	225	297	257	335	290	376	325
115	217	188	249	216	284	245	320	277	359	311
120	208	180	239	207	272	235	307	265	344	298
125	200	173	229	198	261	226	294	255	330	286
130	192	166	220	191	251	217	283	245	318	275
135	185	160	212	184	242	209	273	236	306	264
140	178	154	205	177	233	201	263	227	295	255
145	172	149	198	171	225	194	254	220	285	246
150	166	144	191	165	217	188	245	212	275	238
155	161	139	185	160	210	182	237	205	266	230
160	156	135	179	155	204	176	230	199	258	223
165	151	131	174	150	198	171	223	193	250	216
170	147	127	168	146	192	166	216	187	243	210
175	142	123	164	142	186	161	210	182	236	204
180	138	120	159	138	181	157	204	177	229	198
185	135	116	155	134	176	152	199	172	223	193
190	131	113	151	130	171	148	194	167	217	188
195	128	110	147	127	167	144	189	163	212	183
200	125	108	143	124	163	141	184	159	206	178
210	119	103	136	118	155	134	175	151	196	170
220	113	98	130	112	148	128	167	145	187	162
230	108	94	124	108	142	122	160	138	179	155
240	104	90	119	103	136	117	153	132	172	149
250	100	86	114	99	130	113	147	127	165	143
260	96	83	110	95	125	108	141	122	159	137
270	92	80	106	92	121	104	136	118	153	132
280	89	77	102	88	116	100	131	113	147	127
290	86	74	99	85	112	97	127	110	142	123
300	83	72	95	82	108	94	122	106	137	119

MAXIMUM PITCH IN INCHES FOR SCREWED STAYBOLTS WITH ENDS RIVETED OVER

(For Flat Surfaces)

Pressure Lbs. per sq. inch	Thickness of Plate (Inches)																
	1/4	9/32	5/16	11/32	3/8	13/32	7/16	15/32	1/2	17/32	9/16	19/32	5/8	21/32	11/16	23/32	3/4
25	8 7/16																
30	7 3/4																
35	7 1/8	8 1/16															
40	6 11/16	7 1/2	8 5/16														
45	6 5/16	7 1/16	7 7/8														
50	6	6 3/4	7 1/2	8 1/4													
55	5 11/16	6 7/16	7 1/8	7 13/16													
60	5 7/16	6 1/8	6 13/16	7 1/2	8 3/16												
65	5 1/4	5 7/8	6 9/16	7 3/16	7 7/8												
70	5 1/16	5 11/16	6 5/16	6 15/16	7 5/8	8 3/16											
75	4 7/8	5 1/2	6 1/16	6 13/16	7 5/16	7 15/16											
80	4 3/4	5 5/16	5 7/8	6 1/2	7 1/8	7 11/16	8 1/4										
85	4 5/8	5 1/8	5 3/4	6 5/16	6 7/8	7 7/16	8										
90	4 7/16	5	5 9/16	6 1/8	6 11/16	7 1/4	7 13/16										
95	4 5/16	4 7/8	5 7/16	6	6 1/2	7 1/16	7 5/8	8 7/16									
100	4 1/4	4 3/4	5 5/16	5 13/16	6 3/8	6 7/8	7 7/16	8 3/16									
105	4 1/8	4 5/8	5 3/16	5 11/16	6 3/16	6 11/16	7 1/4	8									
110	4	4 9/16	5 1/16	5 9/16	6 1/16	6 9/16	7 1/16	7 13/16	8 3/8								
115	3 15/16	4 7/16	4 15/16	5 7/16	5 15/16	6 7/16	6 7/8	7 5/8	8 3/16								
120	3 7/8	4 3/8	4 13/16	5 5/16	5 13/16	6 1/4	6 3/4	7 1/2	8	8 1/2							
125	3 3/4	4 1/4	4 3/4	5 3/16	5 11/16	6 1/8	6 5/8	7 3/8	7 13/16	8 5/16							
130	3 11/16	4 3/16	4 5/8	5 1/8	5 9/16	6	6 1/2	7 3/16	7 11/16	8 3/16							
135	3 5/8	4 1/8	4 9/16	5	5 1/2	5 15/16	6 3/8	7 1/16	7 9/16	8	8 1/2						
140	3 9/16	4	4 1/2	4 15/16	5 3/8	5 13/16	6 5/16	6 15/16	7 3/8	7 7/8	8 5/16						
145	3 1/2	3 15/16	4 3/8	4 13/16	5 1/4	5 11/16	6 1/8	6 13/16	7 1/4	7 3/4	8 3/16						
150		3 7/8	4 5/16	4 3/4	5 3/16	5 5/8	6 1/16	6 11/16	7 1/8	7 5/8	8 1/16	8 1/2					
160		3 3/4	4 3/16	4 5/8	5	5 7/16	5 7/8	6 1/2	6 15/16	7 3/8	7 13/16	8 1/4					
170		3 5/8	4 1/16	4 7/16	4 7/8	5 1/4	5 11/16	6 5/16	6 3/4	7 1/8	7 9/16	8	8 3/8				
175		3 5/8	4	4 3/8	4 13/16	5 3/16	5 5/8	6 3/16	6 5/8	7 1/16	7 7/16	7 7/8	8 5/16				
180		3 9/16	3 15/16	4 5/16	4 3/4	5 1/8	5 1/2	6 1/8	6 1/2	6 15/16	7 3/8	7 3/4	8 3/16				
190			3 13/16	4 3/16	4 5/8	5	5 3/8	5 15/16	6 3/8	6 3/4	7 1/8	7 9/16	7 15/16	8 5/16			
200			3 3/4	4 1/8	4 1/2	4 7/8	5 1/4	5 13/16	6 3/16	6 9/16	6 15/16	7 3/8	7 3/4	8 1/8			
210			3 5/8	4	4 3/8	4 3/4	5 1/8	5 11/16	6 1/16	6 7/16	6 13/16	7 3/16	7 9/16	7 15/16	8 5/16		
220			3 9/16	3 15/16	4 5/16	4 5/8	5	5 9/16	5 7/8	6 1/4	6 5/8	7	7 3/8	7 3/4	8 1/8	8 1/2	
230			3 1/2	3 13/16	4 3/16	4 9/16	4 7/8	5 7/16	5 3/4	6 1/8	6 1/2	6 7/8	7 3/16	7 9/16	7 15/16	8 5/16	
240				3 3/4	4 1/8	4 7/16	4 3/4	5 5/16	5 5/8	6	6 3/8	6 11/16	7 1/16	7 7/16	7 3/4	8 1/8	8 1/2
250				3 11/16	4	4 3/8	4 11/16	5 3/16	5 9/16	5 7/8	6 1/4	6 9/16	6 15/16	7 1/4	7 5/8	7 15/16	8 5/16

The above table for pitch of staybolts on flat surfaces is based on the formula:

$$p = \sqrt{\frac{C\ T^2}{P}}$$

where p = maximum pitch between centers of staybolts, inches.

P = maximum allowable working pressure, lbs. per sq. in.

T = the number of sixteenths of an inch in the plate thickness.

C = 112 for plates not over 7/16″ thick.

C = 120 for plates more than 7/16″ thick.

For cylindrical furnaces which require staying, the pitch may be increased somewhat over that allowed for flat surfaces, the formula for such cases being

$$p = \sqrt{\frac{C\ T^2\ R}{P\ R - 250\ T}}$$

where R = the internal radius of the furnace in inches and the other letters have the same significance as above.

ALLOWABLE LOADS ON SOLID STAYBOLTS WITH 12 V-THREADS PER INCH OF LENGTH

The following table is based on a stress of 7500 pounds per square inch of net cross-sectional area and is intended for use with staybolts less than twenty (20) diameters long, screwed through plates, with ends riveted over. For use in boilers having a grate area in excess of fifteen (15) square feet, it is recommended that the outside ends of solid staybolts which have a length of eight inches (8″) or less shall be drilled with a hole 3/16 inch in diameter to a depth of at least 1/2 inch beyond the inside of the plate. The area of this hole must be deducted in figuring the net cross-sectional area of the staybolt and the table shows the allowable loads under this condition as well as the allowable loads for solid staybolts which are not drilled. In each case the area is figured from the diameter at the bottom of the thread.

Diameter of Staybolt (Inches)		Diameter at Bottom of Thread (Inches)	AREA AT BOTTOM OF THREAD (SQUARE INCHES)		ALLOWABLE LOAD (LBS.)	
			Not Drilled	3/16″ Hole Deducted	Not Drilled	Drilled (3/16″ Hole)
3/4	0.7500	0.6057	0.2881	0.2605	2160	1953
13/16	0.8125	0.6682	0.3507	0.3231	2630	2423
7/8	0.8750	0.7307	0.4193	0.3917	3144	2937
15/16	0.9375	0.7932	0.4941	0.4665	3705	3498
1	1.0000	0.8557	0.5751	0.5475	4313	4106
1 1/16	1.0625	0.9182	0.6622	0.6346	4966	4759
1 1/8	1.1250	0.9807	0.7554	0.7278	5665	5458
1 3/16	1.1875	1.0432	0.8547	0.8271	6410	6203
1 1/4	1.2500	1.1057	0.9602	0.9326	7201	6994
1 5/16	1.3125	1.1682	1.0718	1.0442	8038	7831
1 3/8	1.3750	1.2307	1.1897	1.1621	8922	8715
1 7/16	1.4375	1.2932	1.3135	1.2859	9851	9644
1 1/2	1.5000	1.3557	1.4435	1.4159	10826	10619

To figure the allowable pressure on a flat surface supported by staybolts the gross area supported by each stay should be determined from the full pitch dimensions and the net area can then be obtained by deducting the area occupied by the staybolt itself. The allowable working pressure in pounds per square inch is the quotient of the allowable load as given in the table divided by the net area supported. For example: With 1-inch staybolts pitched 5 inches on centers in each direction the gross area supported by each staybolt is 25 square inches and the net area is 25 minus 0.5751 = 24.4249 square inches. If each staybolt is drilled with a 3/16-inch hole the allowable load as given in the table is 4106 pounds and the allowable pressure will be 4106 divided by 24.4249 or 168 pounds per square inch. Of course the spacing and plate thickness must conform to the requirements as given on the opposite page for the stated pressure.

TABLES SHOWING THE LEAST ANGLE WHICH A STAYBOLT MAY MAKE WITH A PLATE TO SECURE A GIVEN NUMBER OF FULL THREADS

(Based on V-threads, 12 to the inch)

Table 1. 4 Full Threads

Thickness of Plate	DIAMETER OF STAYBOLT							
	1/2"	5/8"	3/4"	7/8"	1"	1 1/8"	1 1/4"	1 3/8"
1/4"	.....	.....	.....	.....	.....	.....	.....	.....
5/16"	.....	.....	.....	.....	.....	.....	.....	.....
3/8"	.....	.....	90°*	.....	.....	.....	.....	.....
7/16"	90°	89°	88.5°	89.5°	89°	87°	90°	90°
1/2"	83°	84°	83°	84°	84°	85°	85°	87°
9/16"	76°	78°	78°	81°	84°	83°	83°	85°
5/8"	54°	68°	71°	75°	77°	79°	80°	82°
3/4"	.....	48°	56°	64°	68°	71°	73°	77°
7/8"	.....	.....	28°	51°	60°	64°	67°	72°
1"	.....	.....	.....	30°	48°	61°	60°	64°

Table II. 3 Full Threads

Thickness of Plate	DIAMETER OF STAYBOLT							
	1/2"	5/8"	3/4"	7/8"	1"	1 1/8"	1 1/4"	1 3/8"
1/4"	.....	.....	.....	.....	.....	.....	.....	.....
5/16"	.....	90°*	90°	.....	.....	90°	90°*	.....
3/8"	87°	85°	85°	88°	88°	86°	89°	90°
7/16"	80°	80°	82°	84°	85°	83°	85°	88°
1/2"	70°	72°	75°	79°	80°	80°	83°	85°
9/16"	62°	66°	71°	75°	78°	78°	80°	82°
5/8"	.....	55°	63°	69°	71°	71°	77°	78°
3/4"	.....	.....	46°	59°	64°	65°	70°	73°
7/8"	.....	.....	.....	43°	55°	58°	65°	68°
1"	.....	.....	.....	.....	42°	48°	57°	61°

Table III. 2 Full Threads

Thickness of Plate	DIAMETER OF STAYBOLT							
	1/2"	5/8"	3/4"	7/8"	1"	1 1/8"	1 1/4"	1 3/8"
1/4"	.....	.....	90°*	90°	90°*	90°	90°	.....
5/16"	85°	85°	86°	86°	87°	85°	87°	88°
3/8"	78°	78°	81°	81°	84°	82°	84°	87°
7/16"	69°	73°	76°	78°	80°	79°	82°	83°
1/2"	57°	65°	69°	72°	74°	75°	78°	81°
9/16"	48°	60°	64°	68°	72°	73°	75°	77°
5/8"	.....	44°	55°	60°	66°	67°	73°	76°
3/4"	.....	.....	36°	50°	57°	61°	67°	69°
7/8"	.....	.....	.....	35°	48°	53°	60°	64°
1"	.....	.....	.....	.....	35°	44°	52°	57°

An asterisk (*) signifies that the specified number of threads will be scant.

SPHERICAL HEADS, "PLUS" AND "MINUS"

(A "Hartford" Idea in Nomenclature)

Much confusion has resulted in the use of the terms "bumped," "dished," "concave" and "convex" as applied to spherical heads of cylindrical vessels such as boilers, tanks, drums, etc. The terms "bumped" and "dished" are used interchangeably by many people and the terms "concave" and "convex" are not sufficiently definite unless some explanatory phrase is added to indicate whether the observer is supposed to be on the outside looking in, or on the inside looking out. In the case of a head which curves outwardly from the shell and which is concave to the pressure, the volume enclosed by the head is added to the volume of the shell, thus making a larger vessel than would be the case if a flat head were used; such heads are called "*plus*" heads in our Engineering Department. Similarly, if a head is convex to the pressure, curving inwardly from the shell, its volume will be subtracted from that which the vessel would have with a flat head and it would be called a "*minus*" head.

The tables on Pages 32, 33, 34 and 35 show the allowable working pressure on spherical heads of various thicknesses and diameters. The table for Plus heads without manholes is based on the formula:

$$t=\frac{5.5\times P\times L}{2\times T.\,S.}+\tfrac{1}{8} \text{ or } P=\frac{(2\times T.\,S.)\ (t-\tfrac{1}{8})}{5.5\times L}$$

Where t = the thickness of the head in inches.
P = the maximum allowable working pressure in pounds per sq. in.
T.S. = the tensile strength of the steel in pounds per sq. in. = 55000.
L = the radius to which the head is bumped, in inches.
Substituting the value of the tensile strength, the formula reduces to:

$$P=\frac{20000t-2500}{L}$$

For Plus heads containing manholes the formula is:

$$P=\frac{(2\times T.\,S.)\ (t-\tfrac{1}{4})}{5.5\times L}=\frac{20000\ t-5000}{L}$$

For Minus heads the maximum pressure is figured at sixty per cent (60%) of that allowed on Plus heads of the same dimensions.

In using the tables a radius equal to at least eighty per cent (80%) of the shell diameter should be employed in any case where the actual radius to which the head is bumped or dished is less than this amount.

ALLOWABLE WORKING PRESSURES ON SPHERICAL HEADS

Plus Heads (Concave to Pressure) Without Manhole

Thickness	Radius to which head is bumped (Inches)																				
	12	14	16	18	20	22	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108
1/4″	208.3	178.5	156.2	138.8	125.0	113.6	104.1	83.3	69.4	59.5	52.0	46.2	41.6	37.8	34.7	32.0	29.7	27.7	26.0	24.5	23.1
9/32″	260.4	223.2	195.3	173.6	156.2	142.0	130.2	104.1	86.8	74.4	65.1	57.8	52.0	47.3	43.4	40.0	37.2	34.7	32.5	30.6	28.9
5/16″	312.5	267.8	234.3	208.3	187.5	170.4	156.2	125.0	104.1	89.2	78.1	69.4	62.5	56.8	52.0	48.0	44.6	41.6	39.0	36.7	34.7
11/32″	364.5	312.5	273.4	243.0	218.7	198.8	182.2	145.8	121.5	104.1	91.1	81.0	72.9	66.2	60.7	56.0	52.0	48.6	45.5	42.8	40.5
3/8″	416.6	357.1	312.5	277.7	250.0	227.2	208.3	166.6	138.8	119.0	104.1	92.5	83.3	75.7	69.4	64.1	59.5	55.5	52.0	49.0	46.2
13/32″	468.7	401.7	351.5	312.5	281.2	255.6	234.3	187.5	156.2	133.9	117.1	104.1	93.7	85.2	78.1	72.1	66.9	62.5	58.5	55.1	52.0
7/16″	520.8	446.4	390.6	347.2	312.5	284.0	260.4	208.3	173.6	148.8	130.2	115.7	104.1	94.6	86.8	80.1	74.4	69.4	65.1	61.2	57.8
15/32″	572.9	491.0	429.6	381.9	343.7	312.5	286.4	229.1	190.9	163.6	143.2	127.3	114.5	104.1	95.4	88.1	81.8	76.3	71.6	67.4	63.6
1/2″	625.0	535.7	468.7	416.6	375.0	340.9	312.5	250.0	208.3	178.5	156.2	138.8	125.0	113.6	104.1	96.1	89.2	83.3	78.1	73.5	69.4
17/32″	677.0	580.3	507.8	451.3	406.2	369.3	338.5	270.8	225.6	193.4	169.2	150.4	135.4	123.1	112.8	104.1	96.7	90.2	84.6	79.6	75.2
9/16″	729.1	625.0	546.8	486.1	437.5	397.7	364.5	291.6	243.0	208.3	182.2	162.0	145.8	132.5	121.5	112.1	104.1	97.2	91.1	85.7	81.0
19/32″	781.2	669.6	585.9	520.8	468.7	426.1	390.6	312.5	260.4	223.2	195.3	173.6	156.2	142.0	130.2	120.1	111.6	104.1	97.6	91.9	86.8
5/8″	833.3	714.2	625.0	555.5	500.0	454.5	416.6	333.3	277.7	238.0	208.3	185.1	166.6	151.5	138.8	128.2	119.0	111.1	104.1	98.0	92.5
21/32″	885.4	758.9	664.0	590.2	531.2	482.9	442.7	354.1	295.1	252.9	221.3	196.7	177.0	160.9	147.5	136.2	126.4	118.0	110.6	104.1	98.3
11/16″	937.5	803.5	703.1	625.0	562.5	511.3	468.7	375.0	312.5	267.8	234.3	208.3	187.5	170.4	156.2	144.2	133.9	125.0	117.1	110.2	104.1
23/32″	989.5	848.2	742.1	659.7	593.7	539.7	494.7	395.8	329.8	282.7	247.3	219.9	197.9	179.9	164.9	152.2	141.3	131.9	123.6	116.4	109.9
3/4″	1041.6	892.8	781.2	694.4	625.0	568.1	520.8	416.6	347.2	297.6	260.4	231.4	208.3	189.3	173.6	160.2	148.8	138.8	130.2	122.5	115.7
25/32″	1093.7	937.5	820.3	729.1	656.2	596.5	546.8	437.5	364.5	312.5	273.4	243.0	218.7	198.8	182.2	168.2	156.2	145.8	136.7	128.6	121.5
13/16″	1145.8	982.1	859.3	763.8	687.5	625.0	572.9	458.3	381.9	327.3	286.4	254.6	229.1	208.3	190.9	176.2	163.6	152.7	143.2	134.8	127.3
27/32″	1197.9	1026.7	898.4	798.6	718.7	653.4	598.9	479.1	399.3	342.2	299.4	266.2	239.5	217.8	199.6	184.2	171.1	159.7	149.7	140.9	133.1
7/8″	1250.0	1071.4	937.5	833.3	750.0	681.8	625.0	500.0	416.6	357.1	312.5	277.7	250.0	227.2	208.3	192.3	178.5	166.6	156.2	147.0	138.8
29/32″	1302.0	1116.0	976.5	868.0	781.2	710.2	651.0	520.8	434.0	372.0	325.5	289.3	260.4	236.7	217.0	200.3	186.0	173.6	162.7	153.1	144.6
15/16″	1354.1	1160.7	1015.6	902.7	812.5	738.6	677.0	541.6	451.3	386.9	338.5	300.9	270.8	246.2	225.6	208.3	193.4	180.5	169.2	159.3	150.4
31/32″	1406.2	1205.3	1054.6	937.5	843.7	767.0	703.1	562.5	468.7	401.7	351.5	312.5	281.2	255.6	234.3	216.3	200.8	187.5	175.7	165.4	156.2
1″	1458.3	1250.0	1093.7	972.2	875.0	795.4	729.1	583.3	486.1	416.6	364.5	324.0	291.6	265.1	243.0	224.3	208.3	194.4	182.2	171.5	162.0

See explanatory notes on Page 31.

ALLOWABLE WORKING PRESSURES ON SPHERICAL HEADS

Plus Heads (Concave to Pressure) With Manhole

Thickness	Radius to which head is bumped. (Inches.)																			
	12	14	16	18	20	22	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108
1/4"																					
9/32"	52.0	44.6	39.0	34.7	31.2	28.4	26.0	20.8	17.3	14.8	13.0	11.5	10.4	9.4	8.6	8.0	7.4	6.9	6.5	6.1	5.7
5/16"	104.1	89.2	78.1	69.4	62.5	56.8	52.0	41.6	34.7	29.7	26.0	23.1	20.8	18.9	17.3	16.0	14.8	13.8	13.0	12.2	11.5
11/32"	156.2	133.9	117.1	104.1	93.7	85.2	78.1	62.5	52.0	44.6	39.0	34.7	31.2	28.4	26.0	24.0	22.3	20.8	19.5	18.3	17.3
3/8"	208.3	178.5	156.2	138.8	125.0	113.6	104.1	83.3	69.4	59.5	52.0	46.2	41.6	37.8	34.7	32.0	29.7	27.7	26.0	24.5	23.1
13/32"	260.4	223.2	195.3	173.6	156.2	142.0	130.2	104.1	86.8	74.4	65.1	57.8	52.0	47.3	43.4	40.0	37.2	34.7	32.5	30.6	28.9
7/16"	312.5	267.8	234.3	208.3	187.5	170.4	156.2	125.0	104.1	89.2	78.1	69.4	62.5	56.8	52.0	48.0	44.6	41.6	39.0	36.7	34.7
15/32"	364.5	312.5	273.4	243.0	218.7	198.8	182.2	145.8	121.5	104.1	91.1	81.0	72.9	66.2	60.7	56.0	52.0	48.6	45.5	42.8	40.5
1/2"	416.6	357.1	312.5	277.7	250.0	227.2	208.3	166.6	138.8	119.0	104.1	92.5	83.3	75.7	69.4	64.1	59.5	55.5	52.0	49.0	46.2
17/32"	468.7	401.7	351.5	312.5	281.2	255.6	234.3	187.5	156.2	133.9	117.1	104.1	93.7	85.2	78.1	72.1	66.9	62.5	58.5	55.1	52.0
9/16"	520.8	446.4	390.6	347.2	312.5	284.0	260.4	208.3	173.6	148.8	130.2	115.7	104.1	94.6	86.8	80.1	74.4	69.4	65.1	61.2	57.8
19/32"	572.9	491.0	429.6	381.9	343.7	312.5	286.4	229.1	190.9	163.6	143.2	127.3	114.5	104.1	95.4	88.1	81.8	76.3	71.6	67.4	63.6
5/8"	625.0	535.7	468.7	416.6	375.0	340.9	312.5	250.0	208.3	178.5	156.2	138.8	125.0	113.6	104.1	96.1	89.2	83.3	78.1	73.5	69.4
21/32"	677.0	580.3	507.8	451.3	406.2	369.3	338.5	270.8	225.6	193.4	169.2	150.4	135.4	123.1	112.8	104.1	96.7	90.2	84.6	79.6	75.2
11/16"	729.1	625.0	546.8	486.1	437.5	397.7	364.5	291.6	243.0	208.3	182.2	162.0	145.8	132.5	121.5	112.1	104.1	97.2	91.1	85.7	81.0
23/32"	781.2	669.6	585.9	520.8	468.7	426.1	390.6	312.5	260.4	223.2	195.3	173.6	156.2	142.0	130.2	120.1	111.6	104.1	97.6	91.9	86.8
3/4"	833.3	714.2	625.0	555.5	500.0	454.5	416.6	333.3	277.7	238.0	208.3	185.1	166.6	151.5	138.8	128.2	119.0	111.1	104.1	98.0	92.5
25/32"	885.4	758.9	664.0	590.2	531.2	482.9	442.7	354.1	295.1	252.9	221.3	196.7	177.0	160.9	147.5	136.2	126.4	118.0	110.6	104.1	98.3
13/16"	937.5	803.5	703.1	625.0	562.5	511.3	468.7	375.0	312.5	267.8	234.3	208.3	187.5	170.4	156.2	144.2	133.9	125.0	117.1	110.2	104.1
27/32"	989.5	848.2	742.1	659.7	593.7	539.7	494.7	395.8	329.8	282.7	247.3	219.9	197.9	179.9	164.9	152.2	141.3	131.9	123.6	116.4	109.9
7/8"	1041.6	892.8	781.2	694.4	625.0	568.1	520.8	416.6	347.2	297.6	260.4	231.4	208.3	189.3	173.6	160.2	148.8	138.8	130.2	122.5	115.7
29/32"	1093.7	937.5	820.3	729.1	656.2	596.5	546.8	437.5	364.5	312.5	273.4	243.0	218.7	198.8	182.2	168.2	156.2	145.8	136.7	128.6	121.5
15/16"	1145.8	982.1	859.3	763.8	687.5	625.0	572.9	458.3	381.9	327.3	286.4	254.6	229.1	208.3	190.9	176.2	163.6	152.7	143.2	134.8	127.3
31/32"	1197.9	1026.7	898.4	798.6	718.7	653.4	598.9	479.1	399.3	342.2	299.4	266.2	239.5	217.8	199.6	184.2	171.1	159.7	149.7	140.9	133.1
1"	1250.0	1071.4	937.5	833.3	750.0	681.8	625.0	500.0	416.6	357.1	312.5	277.7	250.0	227.2	208.3	192.3	178.5	166.6	156.2	147.0	138.8

See Explanatory notes on Page 31.

ALLOWABLE WORKING PRESSURES ON SPHERICAL HEADS

Minus Heads (Convex to Pressure) Without Manhole

Thickness	Radius to which head is dished. (Inches.)																				
	12	14	16	18	20	22	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108
1/4"	124.9	107.1	93.7	83.2	75.0	68.1	62.4	49.9	41.6	35.7	31.2	27.7	24.9	22.6	20.8	19.2	17.8	16.6	15.6	14.7	13.8
9/32"	156.2	133.9	117.1	104.1	93.7	85.2	78.1	62.4	52.0	44.6	39.0	34.6	31.2	28.3	26.0	24.0	22.3	20.8	19.5	18.3	17.3
5/16"	187.5	160.6	140.5	124.9	112.5	102.2	93.7	75.0	62.4	53.5	46.8	41.6	37.5	34.0	31.2	28.8	26.7	24.9	23.4	22.0	20.8
11/32"	218.7	187.5	164.0	145.8	131.2	119.2	109.3	87.4	72.9	62.4	54.6	48.6	43.7	39.7	36.4	33.6	31.2	29.1	27.3	25.6	24.3
3/8"	249.9	214.2	187.5	166.6	150.0	136.3	124.9	99.9	83.2	71.4	62.4	55.5	49.9	45.4	41.6	38.4	35.7	33.3	31.2	29.4	27.7
13/32"	281.2	241.0	210.9	187.5	168.7	153.3	140.5	112.5	93.7	80.3	70.2	62.4	56.2	51.1	46.8	43.2	40.1	37.5	35.1	33.0	31.2
7/16"	312.4	267.8	234.3	208.3	187.5	170.4	156.2	124.9	104.1	89.2	78.1	69.4	62.4	56.7	52.0	48.0	44.6	41.6	39.0	36.7	34.6
15/32"	343.7	294.6	257.7	229.1	206.2	187.5	171.8	137.4	114.5	98.1	85.9	76.3	68.7	62.4	57.2	52.8	49.0	45.7	42.9	40.4	38.1
1/2"	375.0	321.4	281.2	249.9	225.0	204.5	187.5	150.0	124.9	107.1	93.7	83.2	75.0	68.1	62.4	57.6	53.5	49.9	46.8	44.1	41.6
17/32"	406.2	348.1	304.6	270.7	243.7	221.5	203.1	162.4	135.3	116.0	101.5	90.2	81.2	73.8	67.6	62.4	58.0	54.1	50.7	47.7	45.1
9/16"	437.4	375.0	328.0	291.6	262.5	238.6	218.7	174.9	145.8	124.9	109.3	97.2	87.4	79.5	72.9	67.2	62.4	58.3	54.6	51.4	48.6
19/32"	468.7	401.7	351.5	312.4	281.2	255.6	234.3	187.5	156.2	133.9	117.1	104.1	93.7	85.2	78.1	72.0	66.9	62.4	58.5	55.1	52.0
5/8"	499.9	428.5	375.0	333.3	300.0	272.7	249.9	199.9	166.6	142.8	124.9	111.0	99.9	90.9	83.2	76.9	71.4	66.6	62.4	58.8	55.5
21/32"	531.2	455.3	398.4	354.1	318.7	289.7	265.6	212.4	177.0	151.7	132.7	118.0	106.2	96.5	88.5	81.7	75.8	70.8	66.3	62.4	58.9
11/16"	562.5	482.1	421.8	375.0	337.5	306.7	281.2	225.0	187.5	160.6	140.5	124.9	112.5	102.2	93.7	86.5	80.3	75.0	70.2	66.1	62.4
23/32"	593.7	508.9	445.2	395.8	356.2	323.8	296.8	237.4	197.8	169.6	148.3	131.9	118.7	107.9	98.9	91.3	84.7	79.1	74.1	69.8	65.9
3/4"	624.9	535.6	468.7	416.6	375.0	340.8	312.4	249.9	208.3	178.5	156.2	138.8	124.9	113.5	104.1	96.1	89.2	83.2	78.1	73.5	69.4
25/32"	656.2	562.5	492.1	437.4	393.7	357.9	328.0	262.5	218.7	187.5	164.0	145.8	131.2	119.2	109.3	100.9	93.7	87.4	82.0	77.1	72.9
13/16"	687.4	589.2	515.5	458.2	412.5	375.0	343.7	274.9	229.1	196.3	171.8	152.7	137.4	124.9	114.5	105.7	98.1	91.6	85.9	80.8	76.3
27/32"	718.7	616.0	539.0	479.1	431.2	392.0	359.3	287.4	239.5	205.3	179.6	159.7	143.7	130.6	119.7	110.5	102.6	95.8	89.8	84.5	79.8
7/8"	750.0	642.8	562.5	499.9	450.0	409.0	375.0	300.0	249.9	214.2	187.5	166.6	150.0	136.3	124.9	115.3	107.1	99.9	93.7	88.2	83.2
29/32"	781.2	669.6	585.9	520.8	468.7	426.1	390.6	312.4	260.4	223.2	195.3	173.5	156.2	142.0	130.2	120.1	111.6	104.1	97.6	91.8	86.7
15/16"	812.4	696.4	609.3	541.6	487.5	443.1	406.2	324.9	270.7	232.1	203.1	180.5	162.4	147.7	135.3	124.9	116.0	108.3	101.5	95.5	90.2
31/32"	843.7	723.1	632.7	562.5	506.2	460.2	421.8	337.5	281.2	241.0	210.9	187.5	168.7	153.3	140.5	129.7	120.4	112.5	105.4	99.2	93.7
1"	874.9	750.0	656.2	583.3	525.0	477.2	437.4	349.9	291.6	249.9	218.7	194.4	174.9	159.0	145.8	134.5	124.9	116.6	109.3	102.9	97.2

See explanatory notes on Page 31.

ALLOWABLE WORKING PRESSURES ON SPHERICAL HEADS

Minus Heads (Convex to Pressure) With Manhole

Thickness	Radius to which head is Dished. (Inches)																			
	12	14	16	18	20	22	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108
1/4"																					
9/32"	31.2	26.7	23.4	20.8	18.7	17.0	15.6	12.4	10.3	8.8	7.8	6.9	6.2	5.6	5.1	4.8	4.4	4.1	3.9	3.6	3.4
5/16"	62.4	53.5	46.8	41.6	37.5	34.0	31.2	24.9	20.8	17.8	15.6	13.8	12.4	11.2	10.3	9.6	8.8	8.2	7.8	7.3	6.9
11/32"	93.7	80.3	70.2	62.4	56.2	51.1	46.8	37.5	31.2	26.7	23.4	20.8	18.7	17.0	15.6	14.4	13.3	12.4	11.7	10.9	10.3
3/8"	124.9	107.1	93.7	83.2	75.0	68.1	62.4	49.9	41.6	35.7	31.2	27.7	24.9	22.6	20.8	19.2	17.8	16.6	15.6	14.7	13.8
13/32"	156.2	133.9	117.1	104.1	93.7	85.2	78.1	62.4	52.0	44.6	39.0	34.6	31.2	28.3	26.0	24.0	22.3	20.8	19.5	18.3	17.3
7/16"	187.5	160.6	140.5	124.9	112.5	102.2	93.7	75.0	62.4	53.5	46.8	41.6	37.5	34.0	31.2	28.8	26.7	24.9	23.4	22.0	20.8
15/32"	218.7	187.5	164.0	145.8	131.2	119.2	109.3	87.4	72.9	62.4	54.6	48.6	43.7	39.7	36.4	33.6	31.2	29.1	27.3	25.6	24.3
1/2"	249.9	214.2	187.5	166.6	150.0	136.3	124.9	99.9	83.2	71.4	62.4	55.5	49.9	45.4	41.6	38.4	35.7	33.3	31.2	29.4	27.7
17/32"	281.2	241.0	210.9	187.5	168.7	153.3	140.5	112.5	93.7	80.3	70.2	62.4	56.2	51.1	46.8	43.2	40.1	37.5	35.1	33.0	31.2
9/16"	312.4	267.8	234.3	208.3	187.5	170.4	156.2	124.9	104.1	89.2	78.1	69.4	62.4	56.7	52.0	48.0	44.6	41.6	39.0	36.7	34.6
19/32"	343.7	294.6	257.7	229.1	206.2	187.5	171.8	137.4	114.5	98.1	85.9	76.3	68.7	62.4	57.2	52.8	49.0	45.7	42.9	40.4	38.1
5/8"	375.0	321.4	281.2	249.9	225.0	204.5	187.5	150.0	124.9	107.1	93.7	83.2	75.0	68.1	62.4	57.6	53.5	49.9	46.8	44.1	41.6
21/32"	406.2	348.1	304.6	270.7	243.7	221.5	203.1	162.4	135.3	116.0	101.5	90.2	81.2	73.8	67.6	62.4	58.0	54.1	50.7	47.7	45.1
11/16"	437.4	375.0	328.0	291.6	262.5	238.6	218.7	174.9	145.8	124.9	109.3	97.2	87.4	79.5	72.9	67.2	62.4	58.3	54.6	51.4	48.6
23/32"	468.7	401.7	351.5	312.4	281.2	255.6	234.3	187.5	156.2	133.9	117.1	104.1	93.7	85.2	78.1	72.0	66.9	62.4	58.5	55.1	52.0
3/4"	499.9	428.5	375.0	333.3	300.0	272.7	249.9	199.9	166.6	142.8	124.9	111.0	99.9	90.9	83.2	76.9	71.4	66.6	62.4	58.8	55.5
25/32"	531.2	455.3	398.4	354.1	318.7	289.7	265.6	212.4	177.0	151.7	132.7	118.0	106.2	96.5	88.5	81.7	75.8	70.8	66.3	62.4	58.9
13/16"	562.5	482.1	421.8	375.0	337.5	306.7	281.2	225.0	187.5	160.6	140.5	124.9	112.5	102.2	93.7	86.5	80.3	75.0	70.2	66.1	62.4
27/32"	593.7	508.9	445.2	395.8	356.2	323.8	296.8	237.4	197.8	169.6	148.3	131.9	118.7	107.9	98.9	91.3	84.7	79.1	74.1	69.8	65.9
7/8"	624.9	535.6	468.7	416.6	375.0	340.8	312.4	249.9	208.3	178.5	156.2	138.8	124.9	113.5	104.1	96.1	89.2	83.2	78.1	73.5	69.4
29/32"	656.2	562.5	492.1	437.4	393.7	357.9	328.0	262.5	218.7	187.5	164.0	145.8	131.2	119.2	109.3	100.9	93.7	87.4	82.0	77.1	72.9
15/16"	687.4	589.2	515.5	458.2	412.5	375.0	343.7	274.9	229.1	196.3	171.8	152.7	137.4	124.9	114.5	105.7	98.1	91.6	85.9	80.8	76.3
31/32"	718.7	616.0	539.0	479.1	431.2	392.0	359.3	287.4	239.5	205.3	179.6	159.7	143.7	130.6	119.7	110.5	102.6	95.8	89.8	84.5	79.8
1"	750.0	642.8	562.5	499.9	450.0	409.0	375.0	300.0	249.9	214.2	187.5	166.6	150.0	136.3	124.9	115.3	107.1	99.9	93.7	88.2	83.2

See explanatory notes on Page 31.

ALLOWABLE WORKING PRESSURES ON UNSTAYED CIRCULAR FURNACES

(Lengths exceeding 120 times the plate thickness.)

Start at bottom of diagram with proper length of furnace and follow up vertical line to intersection with line representing plate thickness; from this intersection follow across on horizontal line to intersection with line representing diameter of furnace. Read allowable pressure from the vertical line at this intersection. See example in dotted lines for length of furnace = 132", thickness of plate = 9/16" and diameter of furnace = 22", giving allowable pressure of 118 lbs.

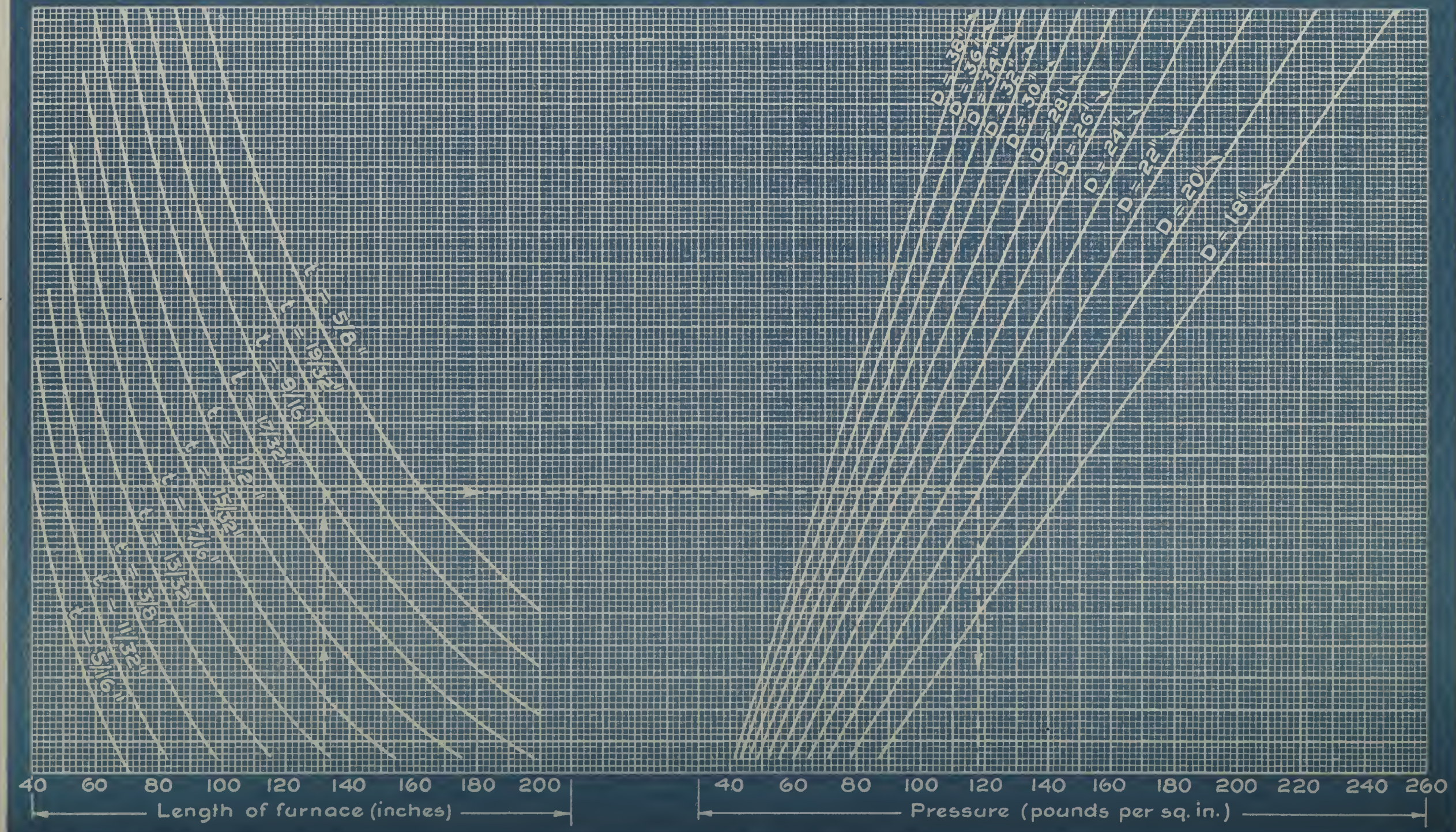
Based on formula $P = \frac{4250 \times T^2}{L \times D}$

P = maximum allowable pressure, lbs. per sq. in.

L = total length of furnace between centers of head rivet seams.

D = outside diameter of furnace, inches.

T = number of sixteenths of an inch in plate thickness.



ALLOWABLE WORKING PRESSURES ON UNSTAYED CIRCULAR FURNACES

(Lengths not exceeding 120 times the plate thickness.)

Start at bottom of diagram with proper length of furnace and follow up vertical line to intersection with line representing plate thickness; from this intersection follow across on horizontal line to intersection with line representing diameter of furnace. Read allowable pressure from the vertical line at this intersection. See example in dotted lines for length of furnace = 42", thickness of plate = 9/16" and diameter of furnace = 30", giving allowable pressure of 215 lbs.

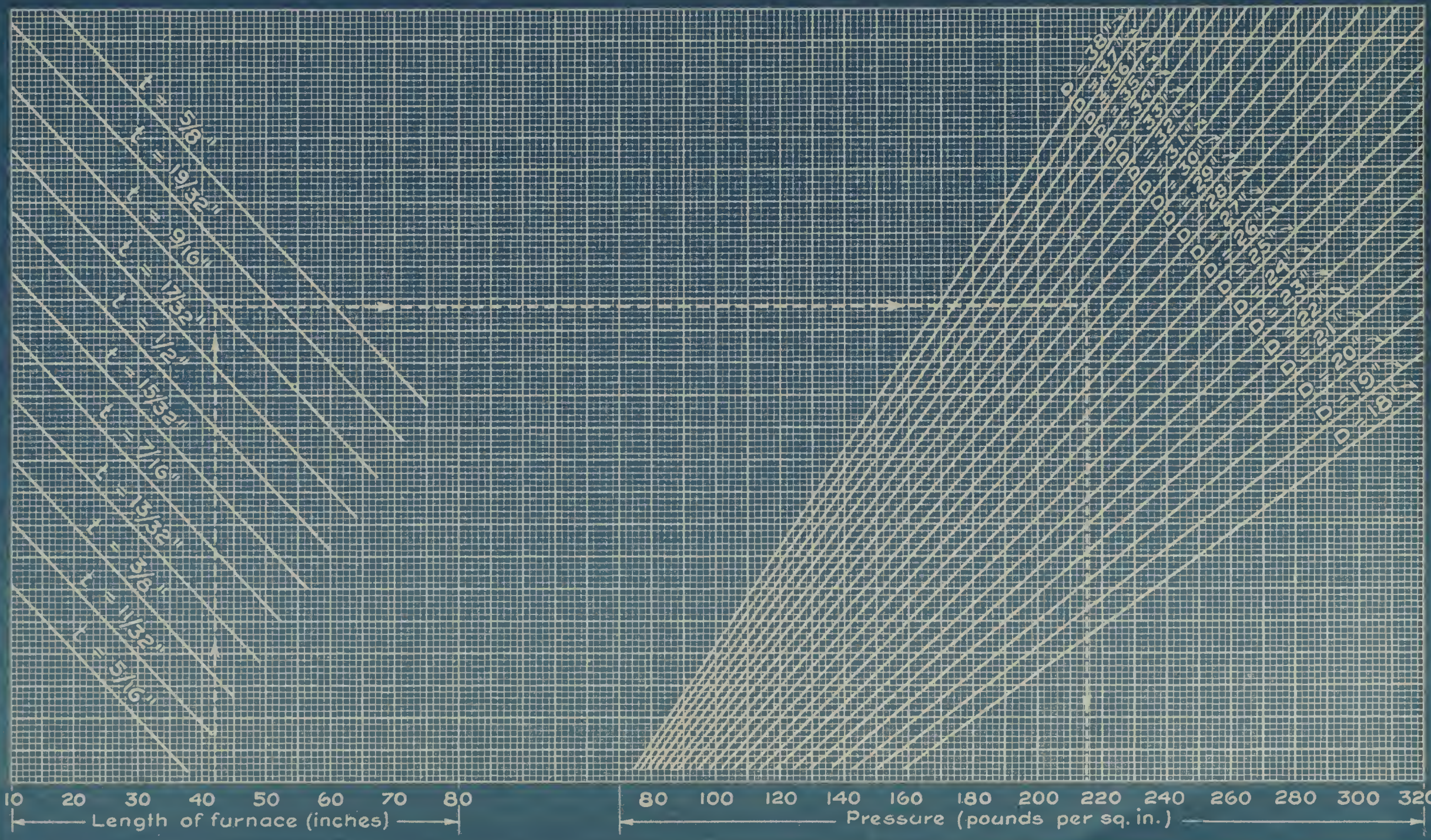
Based on formula $P = \frac{51.5\ (18.75\ T - 1.03\ L)}{D}$

P = maximum allowable pressure, lbs. per sq. in.

D = outside diameter of furnace, inches.

L = total length of furnace between centers of head rivet seams.

T = number of sixteenths of an inch in plate thickness.



TUBES FOR FIRE-TUBE BOILERS

Standard Dimensions

Outside Diameter (Inches)	Standard Thickness (Inches)	Birmingham Wire Gage. (Number)	Inside Diam. (Inches)	Inside Circumference (Inches)	Outside Circumference (Inches)	Length of Tube per Sq. Ft. of Inside Surface (Feet)	Length of Tube per Sq. Ft. of Outside Surface (Feet)	Cross Sectional Area Inside (Sq. In.)	Cross Sectional Area Outside (Sq. In.)	Nominal Weight per Foot. (Pounds)
1	0.072	15	0.85	2.68	3.14	4.46	3.81	0.57	0.78	0.70
1¼	0.072	15	1.10	3.47	3.92	3.45	3.05	0.96	1.22	0.90
1½	0.083	14	1.33	4.19	4.71	2.86	2.54	1.39	1.76	1.24
2	0.095	13	1.80	5.66	6.28	2.11	1.90	2.55	3.14	1.91
2½	0.109	12	2.28	7.17	7.85	1.67	1.52	4.09	4.90	2.75
3	0.109	12	2.78	8.74	9.42	1.37	1.27	6.08	7.06	3.33
3½	0.120	11	3.26	10.24	10.99	1.17	1.09	8.35	9.62	4.28
4	0.134	10	3.74	11.75	12.56	1.02	0.95	10.99	12.56	5.47
4½	0.134	10	4.24	13.32	14.13	0.90	0.84	14.12	15.90	6.17
5	0.148	9	4.72	14.81	15.70	0.80	0.76	17.49	19.63	7.58
6	0.165	8	5.69	17.90	18.84	0.67	0.63	25.50	28.27	10.16

Tubes of the standard thicknesses given in the above table are suitable for pressures up to 175 pounds per square inch. For higher pressures the thickness of tubes should be increased in accordance with the following: For each increase of one gage in thickness above the standard gage shown in the table, the allowable working pressure in pounds per square inch may be increased by an amount equal to the quotient of 200 divided by the diameter of the tube in inches.

TUBES FOR WATER TUBE BOILERS AND SUPERHEATERS

In water tube boilers and superheaters the maximum allowable working pressures for tubes should be determined from the formula:

$$P = \left(\frac{t - 0.039}{D}\right) 18000 - 250$$

where P = maximum allowable working pressure in pounds per sq. in.
t = thickness of tube wall in inches.
D = outside diameter of tube in inches.

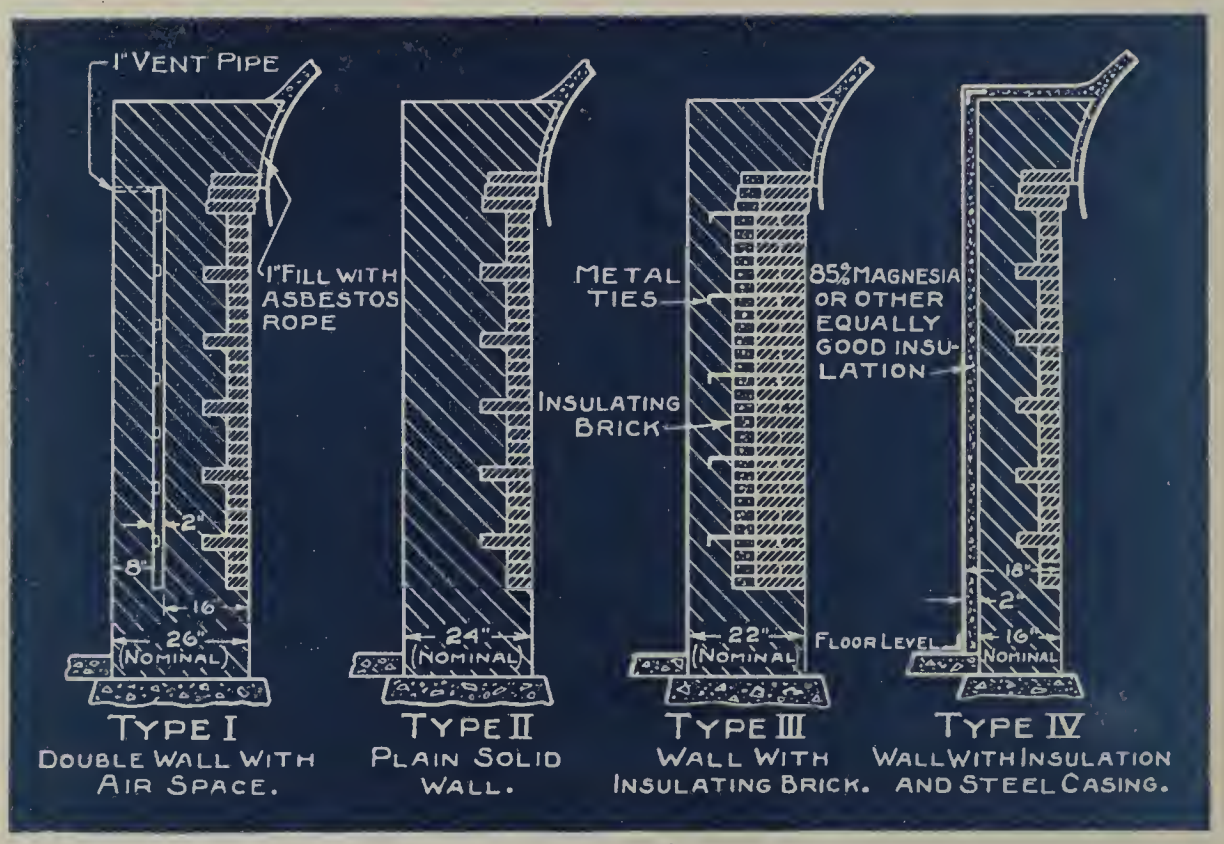
The following table, based on the above formula, shows the maximum allowable working pressures for tubes of various diameters and thicknesses.

Outside diameter of tube, in inches	Gage Number on Birmingham Wire Gage												
	17	16	15	14	13	12	11	10	9	8	7	6	5
D	t = 0.058	t = 0.065	t = 0.072	t = 0.083	t = 0.095	t = 0.109	t = 0.120	t = 0.134	t = 0.148	t = 0.165	t = 0.180	t = 0.203	t = 0.220
½	434	686	938	1334	....	....	....	....	....	....	....	....	...
¾	206	374	542	806	1094	....	....	....	....	....	....	....	...
1	...	218	344	542	758	1010	....	....	....	....	....	....	....
1⅛	...	166	278	454	646	870	1046	....	....	....	....	....	....
1¼	...	124	225	383	557	758	916	1118	....	....	....	....	....
1½	...	...	146	278	422	590	722	890	1058	....	....	....	....
1¾	...	...	...	203	326	470	583	727	871	1046	....	....	....
2	...	...	...	146	254	380	479	605	731	884	1019	....	....
2¼	...	...	...	....	198	310	398	510	622	758	878	1062	....
2½	...	...	...	....	153	254	333	434	535	657	765	931	1053
2¾	...	...	...	....	117	208	280	372	464	575	673	824	935
3	...	...	...	....	....	170	236	320	404	506	596	734	836
3¼	...	...	...	....	....	....	199	276	354	448	531	658	752
3½	...	...	...	....	....	....	167	238	310	398	475	594	681
3¾	...	...	...	....	....	....	139	206	273	355	427	537	619
4	...	...	...	....	....	....	....	178	240	317	385	488	565
4½	...	...	...	....	....	....	....	....	186	254	314	406	474
5	...	...	...	....	....	....	....	....	142	204	258	340	402

HORIZONTAL TUBULAR BOILER SETTINGS

Our setting plans for horizontal tubular boilers have recently been revised and the new drawings show certain features in greater detail than was formerly the case. For each of the common sizes of boilers we have four separate drawings, this number being necessary in order to clearly illustrate the difference between boilers with flush fronts and overhanging fronts and between boilers supported on the side walls and boilers suspended from overhead. Upon application to our Engineering Department blue-prints of any of these drawings will be furnished for use in setting boilers which we insure. In asking for such blue-prints it is necessary to state the diameter of the boiler, the length of tubes, the style of front (flush or overhanging) and the method of support.

Our setting plans illustrate four different types of wall construction, as shown below:



The design shown by Type I is probably used more extensively than any of the others. While it costs but little more than Type II, it has a distinct advantage over that type as regards the prevention of air leakage into the furnace because the cracks will occur principally in the inner wall, leaving the outer wall intact. With a solid wall like that of Type II the cracks will extend clear through the brickwork, thus increasing the probability of air leaks with a resulting excess of air and a lower furnace efficiency. The air space has no virtue as a heat insulator; a double wall of this type will transmit just as much heat under given conditions as a solid wall of the same total thickness.

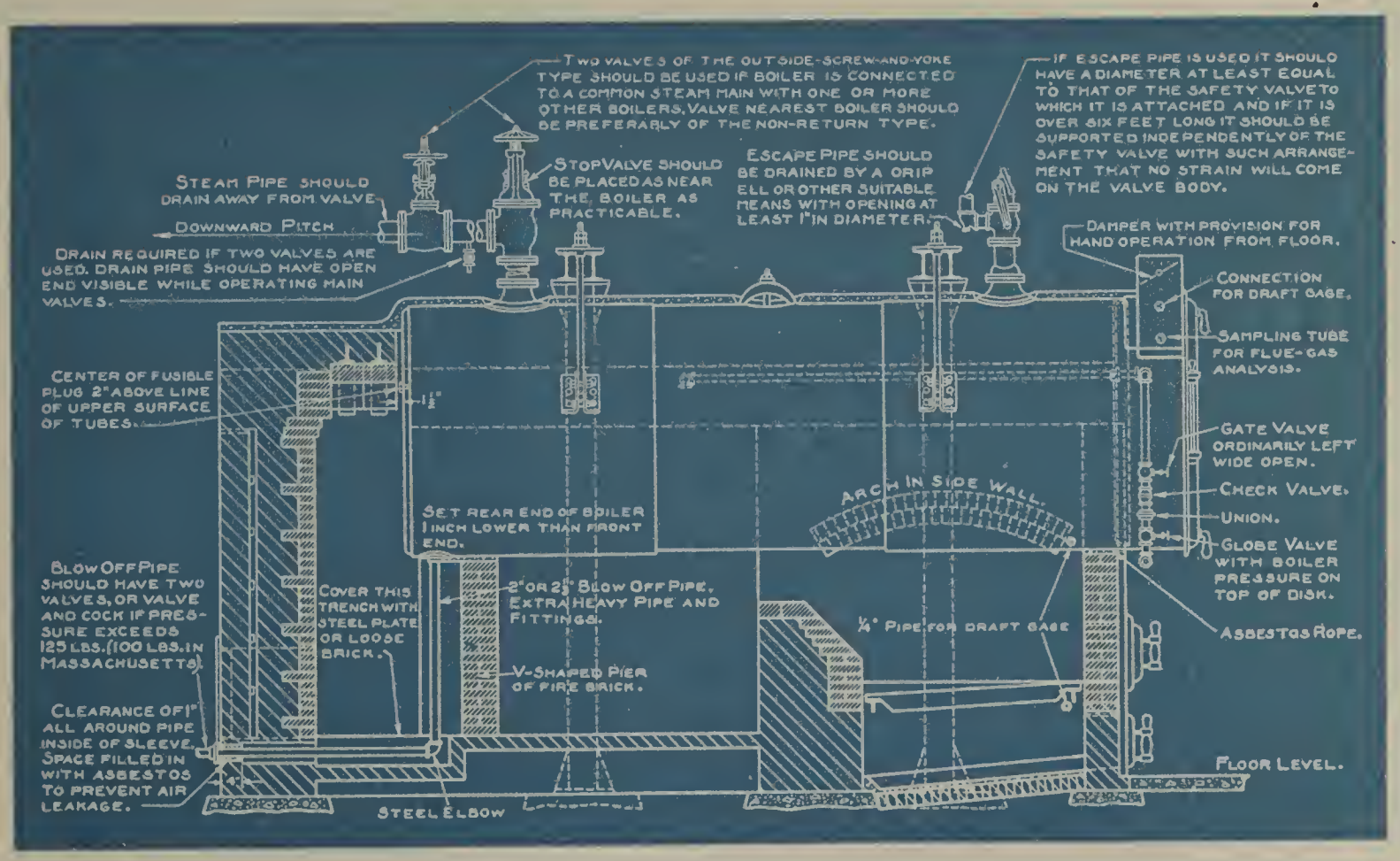
Type III makes use of insulating bricks to reduce the amount of heat that is transmitted through the wall and thereby lost. These insulating bricks are made of different materials by different manufacturers and they are cut to the proper size so that they will lay up evenly with ordinary bricks. They have little mechanical strength in themselves so that it is best to use metal ties, as shown in the cut, for bonding the inner fire-brick section to the common brick on the outside. It is also advisable to use a uniform thickness of nine inches for the fire-brick lining in place of the 4½-inch lining with header courses as shown

for the other types. This type of construction makes a very good setting, costing somewhat more than either Type I or Type II.

Type IV may be considered as similar to Type I with a steel casing substituted for the outer wall and the air space filled with magnesia or other good insulating màterial. This makes a most excellent form of setting, the only drawback to its more general use being its greater cost as compared with other types. The insulating material reduces the heat radiation loss to a minimum and the steel casing prevents the even greater loss due to air leakage through the setting walls. Furthermore, a setting of this kind presents a very neat appearance and requires less space than any of the other types illustrated.

The sections shown are intended to apply to the side walls at the rear of the bridge wall. For the furnace section in front of the bridge wall, we advise that the walls be battered from the grate level to the closing-in line near the middle of the boiler shell. Our drawings show a batter of six inches in this height, thus making the walls that much thicker at the bottom.

The illustration below is a typical longitudinal section through the center of a setting. On the four following pages will be found data on overall dimensions of settings, approximate numbers of bricks required for the various sizes and types, sizes of grates and the heights for setting boilers with different kinds of coal. These tables have been made up from our standard setting plans and it should be understood that they are inter-dependent. They are intended for use with hand-fired horizontal tubular boilers where the combustion rate does not exceed twenty-five (25) pounds of coal per square foot of grate surface per hour and the output is not more than twenty-five per cent (25%) above the nominal rating.



Typical Longitudinal Section Through Center of Horizontal Tubular Boiler Setting.

DIMENSIONS OF SETTINGS FOR HORIZONTAL TUBULAR BOILERS AS SHOWN ON STANDARD SETTING PLANS

Overhanging Fronts

Diam. of Boiler	Length of Tubes	ONE BOILER								TWO BOILERS							
		Type I.		Type II.		Type III.		Type IV.		Type I.		Type II.		Type III.		Type IV.	
		Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
54″	14′	18′– 2″	9′– 4″	18′– 0″	9′– 0″	17′–10″	8′– 8″	17′– 6″	8′– 0″	18′– 2″	16′– 0″	18′– 0″	15′– 8″	17′–10″	15′– 4″	17′– 6″	14′– 8″
54″	16′	20′– 2″	9′– 4″	20′– 0″	9′– 0″	19′–10″	8′– 8″	19′– 6″	8′– 0″	20′– 2″	16′– 0″	20′– 0″	15′– 8″	19′–10″	15′– 4″	19′– 6″	14′– 8″
60″	16′	20′– 2″	9′–10″	20′– 0″	9′– 6″	19′–10″	9′– 2″	19′– 6″	8′– 6″	20′– 2″	17′– 0″	20′– 0″	16′– 8″	19′–10″	16′– 4″	19′– 6″	15′– 8″
60″	18′	22′– 2″	9′–10″	22′– 0″	9′– 6″	21′–10″	9′– 2″	21′– 6″	8′– 6″	22′– 2″	17′– 0″	22′– 0″	16′– 8″	21′–10″	16′– 4″	21′– 6″	15′– 8″
66″	16′	20′– 2″	10′– 4″	20′– 0″	10′– 0″	19′–10″	9′– 8″	19′– 6″	9′– 0″	20′– 2″	18′– 0″	20′– 0″	17′– 8″	19′–10″	17′– 4″	19′– 6″	16′– 8″
66″	18′	22′– 2″	10′– 4″	22′– 0″	10′– 0″	21′–10″	9′– 8″	21′– 6″	9′– 0″	22′– 2″	18′– 0″	22′– 0″	17′– 8″	21′–10″	17′– 4″	21′– 6″	16′– 8″
72″	16′	20′– 2″	10′–10″	20′– 0″	10′– 6″	19′–10″	10′– 2″	19′– 6″	9′– 6″	20′– 2″	19′– 0″	20′– 0″	18′– 8″	19′–10″	18′– 4″	19′– 6″	17′– 8″
72″	18′	22′– 2″	10′–10″	22′– 0″	10′– 6″	21′–10″	10′– 2″	21′– 6″	9′– 6″	22′– 2″	19′– 0″	22′– 0″	18′– 8″	21′–10″	18′– 4″	21′– 6″	17′– 8″
72″	20′	24′– 2″	10′–10″	24′– 0″	10′– 6″	23′–10″	10′– 2″	23′– 6″	9′– 6″	24′– 2″	19′– 0″	24′– 0″	18′– 8″	23′–10″	18′– 4″	23′– 6″	17′– 8″
78″	16′	20′– 2″	11′– 4″	20′– 0″	11′– 0″	19′–10″	10′– 8″	19′– 6″	10′– 0″	20′– 2″	20′– 0″	20′– 0″	19′– 8″	19′–10″	19′– 4″	19′– 6″	18′– 8″
78″	18′	22′– 2″	11′– 4″	22′– 0″	11′– 0″	21′–10″	10′– 8″	21′– 6″	10′– 0″	22′– 2″	20′– 0″	22′– 0″	19′– 8″	21′–10″	19′– 4″	21′– 6″	18′– 8″
78″	20′	24′– 2″	11′– 4″	24′– 0″	11′– 0″	23′–10″	10′– 8″	23′– 6″	10′– 0″	24′– 2″	20′– 0″	24′– 0″	19′– 8″	23′–10″	19′– 4″	23′– 6″	18′– 8″
84″	18′	22′– 8″	11′–10″	22′– 6″	11′– 6″	22′– 4″	11′– 2″	22′– 0″	10′– 6″	22′– 8″	21′– 0″	22′– 6″	20′– 8″	22′– 4″	20′– 4″	22′– 0″	19′– 8″
84″	20′	24′– 8″	11′–10″	24′– 6″	11′– 6″	24′– 4″	11′– 2″	24′– 0″	10′– 6″	24′– 8″	21′– 0″	24′– 6″	20′– 8″	24′– 4″	20′– 4″	24′– 0″	19′– 8″

Flush Fronts

Diam. of Boiler	Length of Tubes	ONE BOILER								TWO BOILERS							
		Type I.		Type II.		Type III.		Type IV.		Type I.		Type II.		Type III.		Type IV.	
		Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
54″	14′	19′– 5″	9′– 4″	19′– 3″	9′– 0″	19′– 1″	8′– 8″	18′– 9″	8′– 0″	19′– 5″	16′– 0″	19′– 3″	15′– 8″	19′– 1″	15′– 4″	18′– 9″	14′– 8″
54″	16′	21′– 5″	9′– 4″	21′– 3″	9′– 0″	21′– 1″	8′– 8″	20′– 9″	8′– 0″	21′– 5″	16′– 0″	21′– 3″	15′– 8″	21′– 1″	15′– 4″	20′– 9″	14′– 8″
60″	16′	21′– 5″	9′–10″	21′– 3″	9′– 6″	21′– 1″	9′– 2″	20′– 9″	8′– 6″	21′– 5″	17′– 0″	21′– 3″	16′– 8″	21′– 1″	16′– 4″	20′– 9″	15′– 8″
60″	18′	23′– 5″	9′–10″	23′– 3″	9′– 6″	23′– 1″	9′– 2″	22′– 9″	8′– 6″	23′– 5″	17′– 0″	23′– 3″	16′– 8″	23′– 1″	16′– 4″	22′– 9″	15′– 8″
66″	16′	21′– 7″	10′– 4″	21′– 5″	10′– 0″	21′– 3″	9′– 8″	20′–11″	9′– 0″	21′– 7″	18′– 0″	21′– 5″	17′– 8″	21′– 3″	17′– 4″	20′–11″	16′– 8″
66″	18′	23′– 7″	10′– 4″	23′– 5″	10′– 0″	23′– 3″	9′– 8″	22′–11″	9′– 0″	23′– 7″	18′– 0″	23′– 5″	17′– 8″	23′– 3″	17′– 4″	22′–11″	16′– 8″
72″	16′	21′– 8″	10′–10″	21′– 6″	10′– 6″	21′– 4″	10′– 2″	21′– 0″	9′– 6″	21′– 8″	19′– 0″	21′– 6″	18′– 8″	21′– 4″	18′– 4″	21′– 0″	17′– 8″
72″	18′	23′– 8″	10′–10″	23′– 6″	10′– 6″	23′– 4″	10′– 2″	23′– 0″	9′– 6″	23′– 8″	19′– 0″	23′– 6″	18′– 8″	23′– 4″	18′– 4″	23′– 0″	17′– 8″
72″	20′	25′– 8″	10′–10″	25′– 6″	10′– 6″	25′– 4″	10′– 2″	25′– 0″	9′– 6″	25′– 8″	19′– 0″	25′– 6″	18′– 8″	25′– 4″	18′– 4″	25′– 0″	17′– 8″
78″	16′	21′–10″	11′– 4″	21′– 8″	11′– 0″	21′– 6″	10′– 8″	21′– 2″	10′– 0″	21′–10″	20′– 0″	21′– 8″	19′– 8″	21′– 6″	19′– 4″	21′– 2″	18′– 8″
78″	18′	23′–10″	11′– 4″	23′– 8″	11′– 0″	23′– 6″	10′– 8″	23′– 2″	10′– 0″	23′–10″	20′– 0″	23′– 8″	19′– 8″	23′– 6″	19′– 4″	23′– 2″	18′– 8″
78″	20′	25′–10″	11′– 4″	25′– 8″	11′– 0″	25′– 6″	10′– 8″	25′– 2″	10′– 0″	25′–10″	20′– 0″	25′– 8″	19′– 8″	25′– 6″	19′– 4″	25′– 2″	18′– 8″
84″	18′	24′– 5″	11′–10″	24′– 3″	11′– 6″	24′– 1″	11′– 2″	23′– 9″	10′– 6″	24′– 5″	21′– 0″	24′– 3″	20′– 8″	24′– 1″	20′– 4″	23′– 9″	19′– 8″
84″	20′	26′– 5″	11′–10″	26′– 3″	11′– 6″	26′– 1″	11′– 2″	25′– 9″	10′– 6″	26′– 5″	21′– 0″	26′– 3″	20′– 8″	26′– 1″	20′– 4″	25′– 9″	19′– 8″

See Pages 40 and 41 for description of different types.

APPROXIMATE NUMBERS OF BRICKS REQUIRED FOR SETTING HORIZONTAL TUBULAR BOILERS IN ACCORDANCE WITH STANDARD SETTING PLANS

Overhanging Fronts

Diam. of Boiler	Length of Tubes	Height From Floor to Center	ONE BOILER								TWO BOILERS							
			Type I.		Type II.		Type III.		Type IV.		Type I.		Type II.		Type III.		Type IV.	
			Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick
54″	14′	6′–7″	15,800	2,450	14,900	2,450	10,500	3,350	9,600	2,450	23,100	4,900	22,100	4,900	17,000	5,700	16,000	4,900
54″	16′	6′–7″	17,300	2,650	16,300	2,650	11,500	3,650	10,500	2,650	25,100	5,300	24,000	5,300	18,400	6,250	17,400	5,300
60″	16′	7′–0″	18,300	2,750	17,400	2,750	12,100	3,900	11,100	2,750	27,000	5,500	25,800	5,500	19,600	6,850	18,500	5,500
60″	18′	7′–0″	19,900	2,950	18,800	2,950	13,100	4,250	12,000	2,950	29,000	5,900	27,800	5,900	21,100	7,400	19,900	5,900
66″	16′	7′–7″	19,700	3,150	18,700	3,150	13,100	4,350	12,000	3,150	29,000	6,300	27,800	6,300	21,200	7,750	20,100	6,300
66″	18′	7′–7″	21,300	3,350	20,300	3,350	14,100	4,700	13,000	3,350	31,200	6,700	29,900	6,700	22,800	8,300	21,600	6,700
72″	16′	8′–2″	21,300	3,450	20,400	3,450	14,100	4,900	13,200	3,450	31,700	6,900	30,600	6,900	23,100	8,650	22,200	6,900
72″	18′	8′–2″	23,000	3,700	22,000	3,700	15,100	5,300	14,200	3,700	34,000	7,400	32,800	7,400	24,800	9,300	23,800	7,400
72″	20′	8′–2″	24,600	3,950	23,700	3,950	16,200	5,700	15,300	3,950	36,200	7,900	35,000	7,900	26,400	9,950	25,500	7,900
78″	16′	8′–9″	23,600	3,800	22,500	3,800	15,600	5,350	14,600	3,800	35,000	7,600	33,700	7,600	25,400	9,500	24,400	7,600
78″	18′	8′–9″	25,400	4,100	24,300	4,100	16,700	5,800	15,700	4,100	37,500	8,200	36,100	8,200	27,300	10,200	26,200	8,200
78″	20′	8′–9″	27,200	4,350	26,100	4,350	17,900	6,200	16,900	4,350	40,000	8,700	38,500	8,700	29,100	10,850	28,000	8,700
84″	18′	9′–4″	27,600	4,600	26,400	4,600	18,300	6,450	17,100	4,600	40,800	9,200	39,300	9,200	29,900	11,500	28,600	9,200
84″	20′	9′–4″	29,500	4,900	28,300	4,900	19,500	6,850	18,300	4,900	43,300	9,800	41,800	9,800	31,700	12,150	30,300	9,800

Flush Fronts

Diam. of Boiler	Length of Tubes	Height From Floor to Center	ONE BOILER								TWO BOILERS							
			Type I.		Type II.		Type III.		Type IV.		Type I.		Type II.		Type III.		Type IV.	
			Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick	Com. Brick	Fire Brick
54″	14′	6′–7″	17,700	2,500	16,700	2,500	12,100	3,450	10,900	2,500	25,900	5,000	24,800	5,000	19,500	6,050	18,200	5,000
54″	16′	6′–7″	19,100	2,700	18,100	2,700	13,000	3,750	11,800	2,700	27,900	5,400	26,700	5,400	20,900	6,600	19,600	5,400
60″	16′	7′–0″	20,300	2,800	19,300	2,800	13,800	4,000	12,600	2,800	30,100	5,600	28,800	5,600	22,300	6,950	21,100	5,600
60″	18′	7′–0″	21,800	2,950	20,700	2,950	14,800	4,300	13,500	2,950	32,100	5,900	30,800	5,900	23,800	7,500	22,600	5,900
66″	16′	7′–7″	22,300	3,200	21,100	3,200	15,200	4,450	13,900	3,200	32,900	6,400	31,600	6,400	24,700	7,850	23,300	6,400
66″	18′	7′–7″	23,900	3,400	22,700	3,400	16,300	4,800	14,800	3,400	35,100	6,800	33,700	6,800	26,300	8,400	24,800	6,800
72″	16′	8′–2″	23,900	3,500	22,900	3,500	16,300	5,000	15,100	3,500	35,700	7,000	34,400	7,000	26,700	8,800	25,400	7,000
72″	18′	8′–2″	25,600	3,750	24,500	3,750	17,400	5,400	16,100	3,750	37,900	7,500	36,600	7,500	28,400	9,400	27,000	7,500
72″	20′	8′–2″	27,300	4,000	26,100	4,000	18,400	5,750	17,100	4,000	40,200	8,000	38,900	8,000	30,000	10,050	28,700	8,000
78″	16′	8′–9″	27,100	3,900	25,900	3,900	18,700	5,450	17,200	3,900	40,600	7,800	39,100	7,800	30,000	9,650	29,100	7,800
78″	18′	8′–9″	29,000	4,150	27,700	4,150	19,900	5,800	18,400	4,150	43,100	8,300	41,600	8,300	32,400	10,350	30,900	8,300
78″	20′	8′–9″	30,800	4,400	29,500	4,400	21,000	6,250	19,500	4,400	45,600	8,800	44,000	8,800	34,300	11,000	32,700	8,800
84″	18′	9′–4″	32,400	4,750	30,900	4,750	22,300	6,700	20,600	4,750	48,200	9,500	46,500	9,500	36,600	11,850	34,700	9,500
84″	20′	9′–4″	34,200	5,050	32,800	5,050	23,500	7,100	21,800	5,050	50,800	10,100	49,000	10,100	38,400	12,550	36,500	10,100

NOTE—This table figured on the basis of 22½ common brick per cubic foot and 17 fire brick per cubic foot with allowance of 3% additional for fire brick. See Pages 40 and 41 for description of different types.

DIMENSIONS OF GRATES FOR HORIZONTAL TUBULAR BOILERS

(As Shown on Standard Setting Plans)

Diameter of Boiler	Length of Tubes	Size of Grates		
		Width	Length	Area (sq. ft.)
54″	14′	4′–0″	4′–0″	16
54″	16′	4′–0″	4′–0″	16
60″	16′	4′–6″	4′–6″	20¼
60″	18′	4′–6″	5′–0″	22½
66″	16′	5′–0″	5′–0″	25
66″	18′	5′–0″	5′–6″	27½
72″	16′	5′–6″	5′–6″	30¼
72″	18′	5′–6″	6′–0″	33
72″	20′	5′–6″	6′–6″	35¾
78″	16′	6′–0″	6′–0″	36
78″	18′	6′–0″	6′–6″	39
78″	20′	6′–0″	7′–0″	42
84″	18′	6′–6″	7′–0″	45½
84″	20′	6′–6″	7′–0″	45½

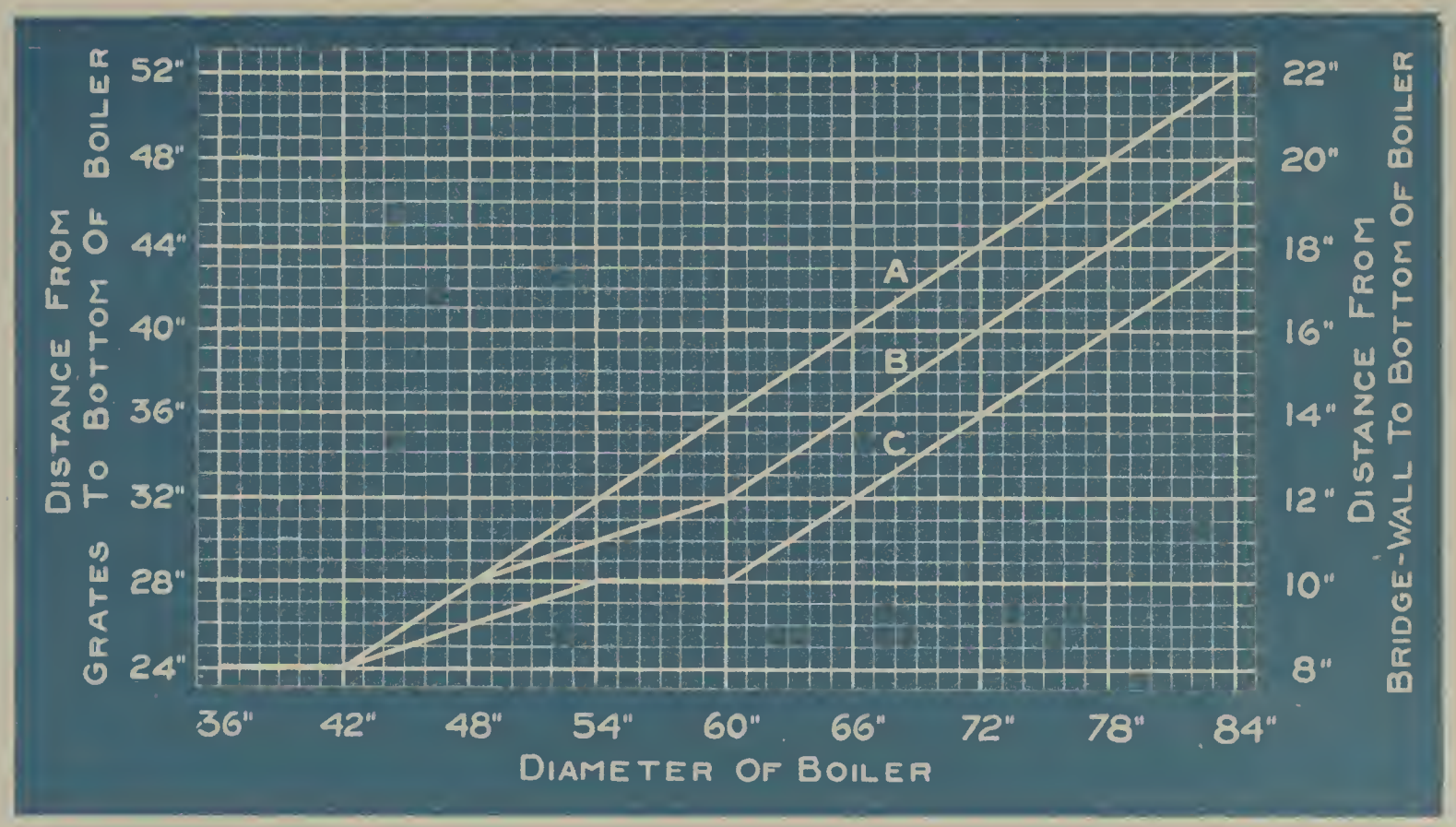
(For hand-fired boilers with combustion rate not exceeding 25 pounds of coal per square foot of grate surface per hour)

Dimensions of Uptakes or Smoke-Openings for Horizontal Tubular Boilers

Diameter of Boiler	Uptake or Smoke Opening		
	Width	Length	Area (sq. in.)
54″	10″	3′–4″	400
60″	10″	4′–6″	540
66″	12″	4′–6″	648
72″	14″	5′–0″	840
78″	14½″	5′–6″	957
84″	17″	6′–0″	1224

RECOMMENDED HEIGHTS FROM GRATES TO SHELL AND FROM BRIDGE-WALL TO SHELL FOR HORIZONTAL TUBULAR BOILER SETTINGS WITH DIFFERENT KINDS OF COAL

(For hand-fired boilers with rate of combustion not exceeding 25 pounds of coal per square foot of grate surface per hour.)



A—For bituminous coals containing more than 35% volatile matter. (Illinois)
B—For bituminous coals containing from 18% to 35% volatile. (Pittsburgh)
C—For anthracite coal and semi-bituminous coal, containing less than 18% volatile. (Pocahontas, George's Creek, etc.)

TABLE OF HEATING SURFACE AND HORSEPOWER FOR STANDARD SIZES OF HORIZONTAL TUBULAR BOILERS WITH MANHOLES BELOW TUBES

Diameter of Boiler	TUBES			HEATING SURFACE (Sq. Ft.)				Horse-Power
	Length	Diameter	Number	Tubes	Shell	Rear Head	Total	
54″	14′	3″	52	531	99	8	638	64
54″	16′	3″	52	607	113	8	728	73
54″	14′	3½″	44	526	99	8	633	63
54″	16′	3½″	44	602	113	8	723	72
54″	14′	4″	36	494	99	7	601	60
54″	16′	4″	36	565	113	7	686	69
60″	16′	3″	74	864	125	9	998	100
60″	18′	3″	74	972	141	9	1122	112
60″	16′	3½″	52	711	125	10	846	85
60″	18′	3½″	52	800	141	10	951	95
60″	16′	4″	46	722	125	9	856	86
60″	18′	4″	46	812	141	9	962	96
66″	16′	3″	94	1098	138	11	1247	125
66″	18′	3″	94	1235	156	11	1402	140
66″	16′	3½″	74	1012	138	11	1161	116
66″	18′	3½″	74	1138	156	11	1305	131
66″	16′	4″	56	878	138	11	1027	103
66″	18′	4″	56	988	156	11	1155	115
72″	16′	3″	122	1425	151	13	1589	159
72″	18′	3″	122	1603	170	13	1786	179
72″	20′	3″	122	1781	188	13	1982	198
72″	16′	3½″	98	1340	151	12	1503	150
72″	18′	3½″	98	1508	170	12	1690	169
72″	20′	3½″	98	1675	188	12	1875	188
72″	16′	4″	74	1161	151	12	1324	132
72″	18′	4″	74	1306	170	12	1488	149
72″	20′	4″	74	1451	188	12	1651	165
78″	16′	3″	146	1705	163	15	1883	188
78″	18′	3″	146	1918	184	15	2117	212
78″	20′	3″	146	2131	204	15	2350	235
78″	16′	3½″	112	1532	163	15	1710	171
78″	18′	3½″	112	1723	184	15	1922	192
78″	20′	3½″	112	1915	204	15	2134	213
78″	16′	4″	91	1427	163	14	1604	160
78″	18′	4″	91	1606	184	14	1804	180
78″	20′	4″	91	1784	204	14	2002	200
84″	18′	3″	176	2312	198	17	2527	253
84″	20′	3″	176	2569	220	17	2806	281
84″	18′	3½″	138	2123	198	16	2337	234
84″	20′	3½″	138	2359	220	16	2595	260
84″	18′	4″	108	1906	198	16	2120	212
84″	20′	4″	108	2118	220	16	2354	235

The above table is figured on the basis of ten (10) square feet of heating surface per boiler horsepower; the heating surface as calculated includes all of the inside tube area, one-half the area of the cylindrical portion of the shell, and two-thirds of the area of the rear head minus the combined cross-sectional area of the tubes.

APPROXIMATE WEIGHTS OF HORIZONTAL TUBULAR BOILERS

The weights of bare boilers as given in the following table are taken from data of the American Boiler Manufacturers' Association, figures being given for boilers designed to operate at pressures of 125 pounds and 150 pounds. These weights do not include fronts, trimmings, grates or other castings. The amount of water contained in a boiler of given diameter and length will vary with the number of tubes and their diameter. The weights given in the last column are figured for average cases, with the boiler entirely filled and allowing 62.5 pounds per cubic foot of water. These weights should be added to the weights of the bare boilers in order to determine the total maximum weight of a boiler as installed, due allowance being made also for the weight of trimmings and other parts which are attached directly to the boiler and supported thereby.

Diameter of Boiler	Length of Tubes	Weight of Bare Boiler, Lbs.		Weight of Water
		125 lbs. Pressure	150 lbs. Pressure	
54″	14′	9100	9700	11700
54″	16′	10100	10800	13400
60″	16′	12400	13400	16300
60″	18′	13600	14800	18400
66″	16′	14900	16300	19100
66″	18′	16400	17800	21500
72″	16′	18400	20000	22500
72″	18′	20000	21700	25300
72″	20′	21700	23300	28100
78″	18′	25000	26400	29600
78″	20′	27100	28600	32900

Approximate Weights in Pounds per Square Foot of Flat Steel Plates

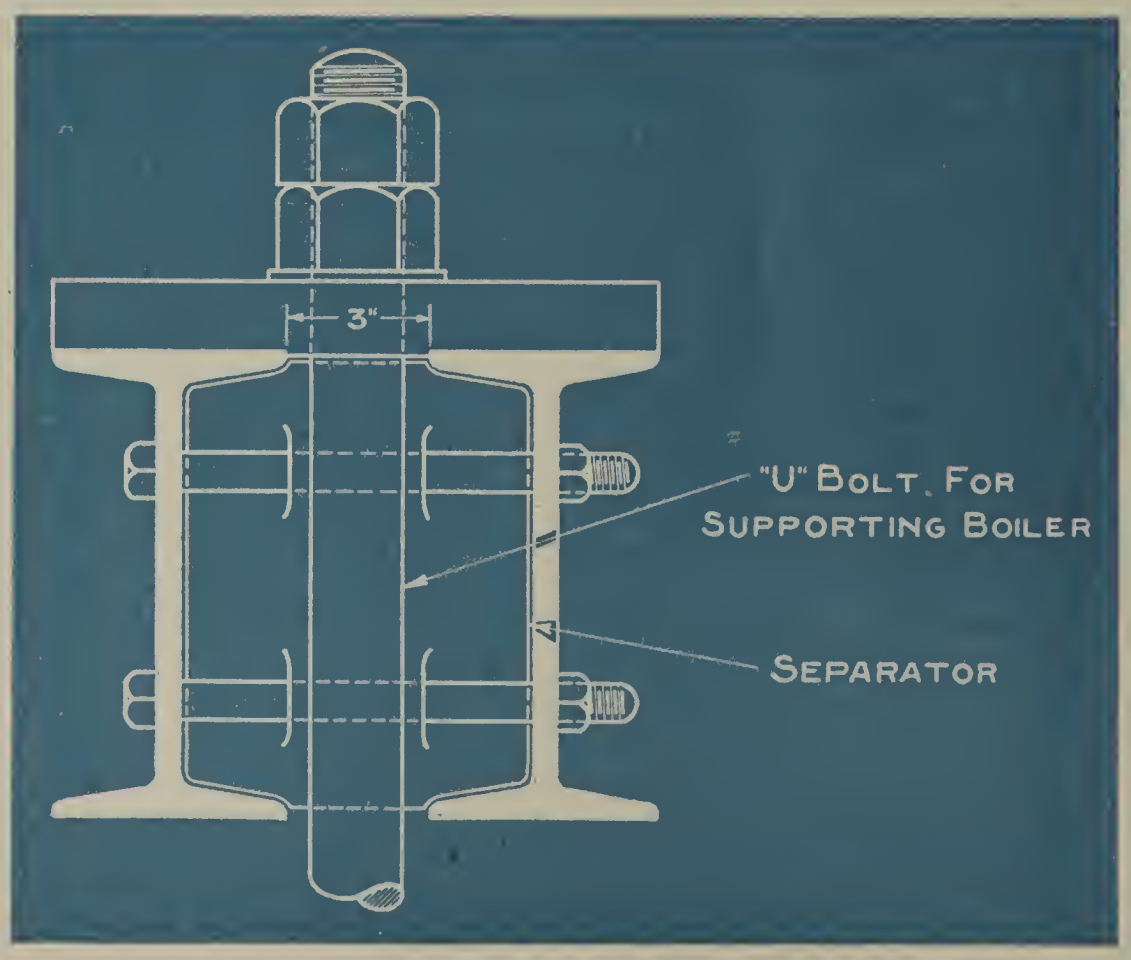
Thickness (Inches)	Weight (Lbs.)	Thickness (Inches)	Weight (Lbs.)
1/4	10.20	5/8	25.50
9/32	11.48	21/32	26.78
5/16	12.75	11/16	28.05
11/32	14.03	23/32	29.33
3/8	15.30	3/4	30.60
13/32	16.58	25/32	31.88
7/16	17.85	13/16	33.15
15/32	19.13	27/32	34.43
1/2	20.40	7/8	35.70
17/32	21.68	29/32	36.98
9/16	22.95	15/16	38.25
19/32	24.23	31/32	39.53
		1	40.80

The above table is based on a weight of 0.2833 pound per cubic inch for steel plate; this corresponds with a specific gravity of 7.854.

I-BEAMS FOR SUSPENDING HORIZONTAL TUBULAR BOILERS

The following table shows the sizes of I-beams which we recommend for the suspension of horizontal tubular boilers of the more common sizes. It is based on a maximum fiber stress of 12500 pounds per square inch, this conservative figure being used because of the fact that such I-beams are often required to carry loads in excess of those due to the boilers. In computing the table, the limiting spans and the locations of the points of suspension were taken from our standard setting plans. It should be understood that four I-beams are required in each case, the beams being bolted together in pairs as shown in the sketch below the table.

Diameter of Boilers	Length of Tubes	Depth of I-Beams and Weight per Foot		
		One Boiler	Two Boilers	Three Boilers
54″	16′	6″–12¼ lbs.	10″–30 lbs.	15″–42 lbs.
60″	16′	7″–15 “	12″–31½ “	18″–55 “
60″	18′	7″–15 “	12″–35 “	18″–55 “
66″	16′	7″–15 “	12″–40 “	18″–55 “
66″	18′	8″–18 “	15″–42 “	18″–60 “
72″	16′	8″–18 “	15″–42 “	20″–65 “
72″	18′	8″–18 “	15″–42 “	20″–65 “
72″	20′	8″–18 “	18″–55 “	24″–80 “
78″	16′	8″–18 “	18″–55 “	24″–80 “
78″	18′	9″–21 “	18″–55 “	24″–80 “
78″	20′	9″–21 “	18″–55 “	24″–80 “
84″	18′	9″–21 “	18″–55 “	24″–80 “
84″	20′	9″–21 “	20″–65 “	24″–90 “



COLUMNS FOR SUPPORTING HORIZONTAL TUBULAR BOILERS

On this page and page 50 will be found tables to show the proper sizes of columns for suspended horizontal tubular boilers. Four types of columns are included, viz:—square cast-iron columns, round cast-iron columns, structural steel H-beams and built-up columns of the plate-and-angle type. No table is given for I-beam columns because the I-beam shape is poorly adapted for use as a column and is not recommended for this purpose. We also have designs for reinforced concrete columns and beams for the usual sizes of horizontal tubular boilers and can furnish copies of the same on application.

The tables for column sizes in structural steel handbooks cannot be applied to the support of boilers, as a rule, because such tables are based on the assumption that the loads are direct and equally distributed over the cross-section of the column, or else balanced on opposite sides thereof, whereas in boiler installations the loads are usually applied entirely at one side, thus introducing bending stresses which must be taken into consideration. There is no simple solution of the problem but it is a matter of much importance and allowance has therefore been made for this condition in the tables which follow. In these tables it is assumed that the columns are not built into the brickwork or braced in any other way against flexure. The maximum ratio of slenderness (=the quotient of the unsupported length of the column divided by its radius of gyration) is taken at 120 for steel and 70 for cast iron. The maximum length as given in the tables for each case should not be exceeded.

We realize that the designs are heavier than those used by some boilermakers but we do not believe that lighter columns should be used except in cases where the loading is non-eccentric or where the columns are braced laterally so as to reduce the effective unsupported length.

Sizes of Round Cast Iron Columns for Suspended Horizontal Tubular Boilers

Diameter of Boilers (Inches)	Length of Tubes (Feet)	Maximum Length of Columns	Diameter and Thickness of Columns		
			One Boiler	Two Boilers	Three Boilers
54	16	10′–6″	7″ x ¾″	7″ x ⅞″	7″ x 1″
60	16	11′–0″	7″ x ¾″	7″ x ⅞″	7″ x 1″
60	18	11′–0″	7″ x ¾″	7″ x ⅞″	7″ x 1″
66	16	12′–0″	8″ x ⅞″	8″ x 1″	8″ x 1⅛″
66	18	12′–0″	8″ x ⅞″	8″ x 1″	8″ x 1⅛″
72	16	13′–0″	9″ x ⅞″	9″ x 1″	9″ x 1⅛″
72	18	13′–0″	9″ x ⅞″	9″ x 1″	9″ x 1⅛″
72	20	13′–0″	9″ x ⅞″	9″ x 1″	9″ x 1⅛″
78	16	13′–6″	9″ x ⅞″	9″ x 1″	9″ x 1⅛″
78	18	13′–6″	9″ x ⅞″	9″ x 1″	9″ x 1⅛″
78	20	13′–6″	9″ x ⅞″	9″ x 1″	9″ x 1⅛″
84	18	14′–0″	9″ x 1⅛″	9″ x 1⅛″	9″ x 1¼″
84	20	14′–0″	10″ x 1″	10″ x 1″	10″ x 1⅛″

Sizes of Square Cast Iron Columns for Suspended Horizontal Tubular Boilers

Diameter of Boilers (Inches)	Length of Tubes (Feet)	Maximum Length of Columns	Width and Thickness of Columns		
			One Boiler	Two Boilers	Three Boilers
54	16	10′–6″	6″ x ¾″	6″ x ⅞″	6″ x 1″
60	16	11′–0″	6″ x ¾″	6″ x ⅞″	6″ x 1″
60	18	11′–0″	6″ x ¾″	6″ x ⅞″	6″ x 1″
66	16	12′–0″	7″ x ¾″	7″ x ⅞″	7″ x 1″
66	18	12′–0″	7″ x ¾″	7″ x ⅞″	7″ x 1″
72	16	13′–0″	8″ x ¾″	8″ x ⅞″	8″ x 1″
72	18	13′–0″	8″ x ¾″	8″ x ⅞″	8″ x 1″
72	20	13′–0″	8″ x ¾″	8″ x ⅞″	8″ x 1″
78	16	13′–6″	8″ x ¾″	8″ x ⅞″	8″ x 1″
78	18	13′–6″	8″ x ¾″	8″ x ⅞″	8″ x 1″
78	20	13′–6″	8″ x ¾″	8″ x ⅞″	8″ x 1″
84	18	14′–0″	8″ x 1″	8″ x 1″	8″ x 1⅛″
84	20	14′–0″	8″ x 1″	8″ x 1″	8″ x 1⅛″

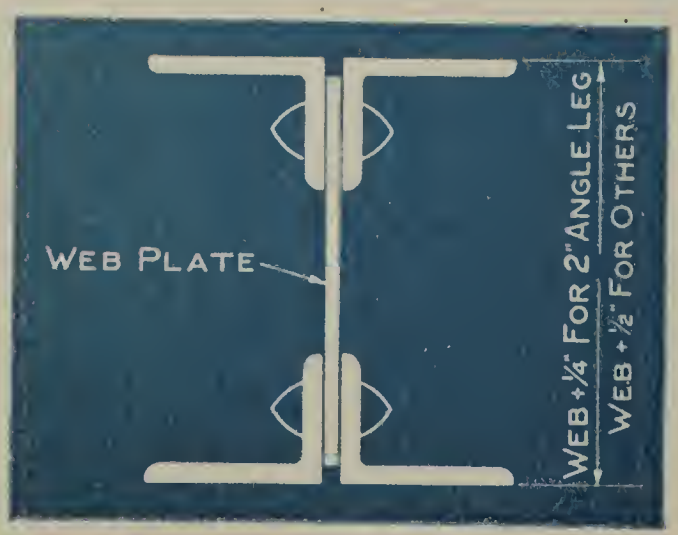
Sizes of H-Beams for Suspended Horizontal Tubular Boilers

Diameter of Boilers	Length of Tubes	Maximum Length of Columns	Depth of H-Beams and Weight per Foot		
			One Boiler	Two Boilers	Three Boilers
54″	16′	10′–6″	5″–18.7 lbs.	5″–18.7 lbs.	6″–23.8 lbs.
60″	16′	11′–0″	5″–18.7 “	6″–23.8 “	8″–34.0 “
60″	18′	11′–0″	5″–18.7 “	6″–23.8 “	8″–34.0 “
66″	16′	12′–0″	5″–18.7 “	8″–34.0 “	8″–34.0 “
66″	18′	12′–0″	5″–18.7 “	8″–34.0 “	
72″	16′	13′–0″	6″–23.8 “	8″–34.0 “	
72″	18′	13′–0″	6″–23.8 “	8″–34.0 “	
72″	20′	13′–0″	6″–23.8 “	8″–34.0 “	
78″	16′	13′–6″	6″–23.8 “	8″–34.0 “	
78″	18′	13′–6″	6″–23.8 “	8″–34.0 “	
78″	20′	13′–6″	8″–34.0 “		
84″	18′	14′–0″	8″–34.0 “		
84″	20′	14′–0″	8″–34.0 “		

See explanatory notes on Page 49.

Sizes of Plate-and-Angle Columns for Suspended Horizontal Tubular Boilers

Diameter of Boilers	Length of Tubes	Maximum Length of Columns	Sizes of Plates-and-Angles		
			One Boiler	Two Boilers	Three Boilers
54″	16′	10′–6″	6″ x ¼″ 3″ x 2″ x ¼″	6″ x ¼″ 3″ x 2″ x ¼″	8″ x ¼″ 3½″ x 2½″ x ¼″
60″	16′	11′–0″	6″ x ¼″ 3″ x 2″ x ¼″	8″ x ¼″ 3″ x 2½″ x 5/16″	8″ x ¼″ 3½″ x 2½″ x 5/16″
60″	18′	11′–0″	6″ x ¼″ 3″ x 2″ x ¼″	8″ x ¼″ 3″ x 2½″ x 5/16″	8″ x 5/16″ 3½″ x 2½″ x ⅜″
66″	16′	12′–0″	8″ x ¼″ 3″ x 2½″ x 5/16″	8″ x ¼″ 3½″ x 2½″ x 5/16″	8″ x 5/16″ 4″ x 3″ x 5/16″
66″	18′	12′–0″	8″ x ¼″ 3″ x 2½″ x 5/16″	8″ x ¼″ 3½″ x 2½″ x 5/16″	8″ x 5/16″ 4″ x 3″ x ⅜″
72″	16′	13′–0″	8″ x ¼″ 3½″ x 2½″ x ¼″	8″ x 5/16″ 3½″ x 2½″ x ⅜″	8″ x ⅜″ 4″ x 3″ x 7/16″
72″	18′	13′–0″	8″ x ¼″ 3½″ x 2½″ x ¼″	8″ x 5/16″ 3½″ x 2½″ x ⅜″	8″ x ⅜″ 4″ x 3″ x 7/16″
72″	20′	13′–0″	8″ x ¼″ 3½″ x 2½″ x ¼″	8″ x 5/16″ 4″ x 3″ x 5/16″	8″ x ⅜″ 4″ x 3″ x ½″
78″	16′	13′–6″	8″ x ¼″ 3½″ x 2½″ x ¼″	8″ x 5/16″ 4″ x 3″ x 5/16″	8″ x ⅜″ 4″ x 3″ x ½″
78″	18′	13′–6″	8″ x ¼″ 3½″ x 2½″ x ¼″	8″ x 5/16″ 4″ x 3″ x ⅜″	10″ x ⅜″ 5″ x 3½″ x ⅜″
78″	20′	13′–6″	8″ x ¼″ 3½″ x 2½″ x 5/16″	8″ x ⅜″ 4″ x 3″ x 7/16″	10″ x ⅜″ 5″ x 3½″ x 7/16″
84″	18′	14′–0″	8″ x ¼″ 3½″ x 2½″ x 5/16″	8″ x ⅜″ 4″ x 3″ x 7/16″	10″ x ⅜″ 5″ x 3½″ x 7/16″
84″	20′	14′–0″	8″ x ¼″ 3½″ x 2½″ x 5/16″	8″ x ⅜″ 4″ x 3″ x ½″	10″ x ⅜″ 6″ x 4″ x ⅜″



NOTE: The columns described in this table are intended to be constructed in accordance with the detail sketch at the left. For each size of boiler the size of the web plate is given above with the size of the angles underneath. Four angles are required in every case. Overall dimensions of the various column cross-sections may be determined by reference to the sketch.

See explanatory notes on Page 49.

SAFETY VALVES FOR POWER BOILERS

The tables on the next four pages give data in regard to the sizes of flat-seat and 45-degree bevel-seat safety valves required for various pressures and for different sizes of boilers as determined by the nominal horsepower rating, this rating in each case being figured on the basis of ten (10) square feet of boiler heating surface per horsepower. (See table on Page 46 for ratings of horizontal tubular boilers). The required relieving capacity of safety valves is based on six (6) pounds of steam per square foot of boiler heating surface per hour for water-tube boilers, five (5) pounds for other types when the pressure exceeds 100 pounds per square inch, and three (3) pounds for such types when the pressure varies between the limits of 15 pounds and 100 pounds per square inch, inclusive. Relieving capacities for intermediate sizes not given in the tables should be figured on the above basis.

The required number and size of safety valves in any case should be determined primarily from the relieving capacity which is dependent upon the lift of the valve as well as its diameter. As a matter of convenience, the tables show the number and diameter of valves required for various conditions based upon assumed lifts as given below:

Diameter of Valve	Assumed Lift
1″	0.04″
1¼″	0.04″
1½″	0.05″
2″	0.06″
2½″	0.06″
3″	0.08″
3½″	0.09″
4″	0.10″
4½″	0.11″

The valve diameters given should be used with caution, the actual lift being considered in each case. When the lift differs from that assumed in the tables the relieving capacity of a valve can be calculated from one of the following formulae:

$W = 155(P+14.7) \times D \times L$ for flat-seat valves.

$W = 110(P+14.7) \times D \times L$ for 45-degree bevel-seat valves.

$W = 50(P+14.7)\ A$ for valves with seats of any angle.

where W = the relieving capacity in pounds per hour.

P = gage pressure in pounds per square inch.

D = inside diameter of valve seat, inches.

L = vertical lift of valve disk measured with 3% excess pressure, inches.

A = relieving area in square inches = $3.1416 \times D \times L \times$ sine of seat angle.

Sizes of Boiler Connections for Two or Three Safety Valves Mounted on a Single Base or Enclosed in a Single Casing

Diameter of Each Valve	Diameter of Opening to Boiler	
	Two Valves	Three Valves
1″	1½″	2″
1¼″	2″	2½″
1½″	2½″	3″
2″	3″	3½″
2½″	4″	4½″
3″	4½″	6″
3½″	5″	7″
4″	6″	7″
4½″	7″	8″

SAFETY VALVES FOR FIRE-TUBE BOILERS

(Pressure Range from 15 lbs. to 100 lbs. Inclusive)

Nominal Horse-power Rating	Required Capacity (Lbs. per Hr.)	NUMBER AND DIAMETER OF SAFETY VALVES REQUIRED WITH AVERAGE LIFT									
		BEVEL SEAT					FLAT SEAT				
		15 lbs.	25 lbs.	50 lbs.	75 lbs.	100 lbs.	15 lbs.	25 lbs.	50 lbs.	75 lbs.	100 lbs.
50	1500	1–4½″	1–4″	1–3″	1–3″	1–2″	1–4″	1–3½″	1–3″	1–2″	1–2″
55	1650	2–3½″	1–4″	1–3″	1–3″	1–2½″	1–4″	1–3½″	1–3″	1–2″	1–2″
60	1800	2–3½″	1–4½″	1–3½″	1–3″	1–2½″	1–4″	1–3½″	1–3″	1–2½″	1–2″
65	1950	2–3½″	1–4½″	1–3½″	1–3″	1–3″	1–4½″	1–4″	1–3″	1–2½″	1–2″
70	2100	2–4″	2–3½″	2–2½″	2–2″	2–2″	2–3″	2–3″	2–2″	2–2″	2–1½″
75	2250	2–4″	2–3½″	2–3″	2–2″	2–2″	2–3½″	2–3″	2–2″	2–2″	2–1½″
80	2400	2–4″	2–3½″	2–3″	2–2½″	2–2″	2–3½″	2–3″	2–2½″	2–2″	2–1½″
85	2550	2–4″	2–3½″	2–3″	2–2½″	2–2″	2–3½″	2–3″	2–2½″	2–2″	2–1½″
90	2700	2–4½″	2–3½″	2–3″	2–2½″	2–2″	2–3½″	2–3″	2–2½″	2–2″	2–1½″
95	2850	2–4½″	2–4″	2–3″	2–2½″	2–2″	2–3½″	2–3″	2–2½″	2–2″	2–2″
100	3000	2–4½″	2–4″	2–3″	2–3″	2–2″	2–4″	2–3½″	2–3″	2–2″	2–2″
105	3150	2–4½″	2–4″	2–3″	2–3″	2–2½″	2–4″	2–3½″	2–3″	2–2″	2–2″
110	3300	3–4″	2–4″	2–3″	2–3″	2–2½″	2–4″	2–3½″	2–3″	2–2″	2–2″
115	3450	3–4″	2–4″	2–3½″	2–3″	2–2½″	2–4″	2–3½″	2–3″	2–2½″	2–2″
120	3600	3–4″	2–4½″	2–3½″	2–3″	2–2½″	2–4″	2–3½″	2–3″	2–2½″	2–2″
125	3750	3–4″	2–4½″	2–3½″	2–3″	2–2½″	2–4½″	2–3½″	2–3″	2–2½″	2–2″
130	3900	3–4″	2–4½″	2–3½″	2–3″	2–3″	2–4½″	2–4″	2–3″	2–2½″	2–2″
135	4050	3–4½″	2–4½″	2–3½″	2–3″	2–3″	2–4½″	2–4″	2–3″	2–2½″	2–2″
140	4200	3–4½″	2–4½″	2–3½″	2–3″	2–3″	2–4½″	2–4″	2–3″	2–3″	2–2″
145	4350	3–4½″	3–4″	2–3½″	2–3″	2–3″	2–4½″	2–4″	2–3″	2–3″	2–2½″
150	4500	3–4½″	3–4″	2–4″	2–3″	2–3″	2–4½″	2–4″	2–3″	2–3″	2–2½″
155	4650	3–4½″	3–4″	2–4″	2–3″	2–3″	3–4″	2–4″	2–3″	2–3″	2–2½″
160	4800	3–4½″	3–4″	2–4″	2–3½″	2–3″	3–4″	2–4″	2–3½″	2–3″	2–2½″
165	4950	4–4″	3–4″	2–4″	2–3½″	2–3″	3–4″	2–4½″	2–3½″	2–3″	2–2½″
170	5100	4–4″	3–4″	2–4″	2–3½″	2–3″	3–4″	2–4½″	2–3½″	2–3″	2–2½″
175	5250	4–4½″	3–4½″	2–4″	2–3½″	2–3″	3–4″	2–4½″	2–3½″	2–3″	2–2½″
180	5400	4–4½″	3–4½″	2–4″	2–3½″	2–3″	3–4″	2–4½″	2–3½″	2–3″	2–2½″
185	5550	4–4½″	3–4½″	2–4″	2–3½″	2–3″	3–4½″	2–4½″	2–3½″	2–3″	2–2½″
190	5700	4–4½″	3–4½″	2–4½″	2–3½″	2–3″	3–4½″	2–4½″	2–3½″	2–3″	2–3″
195	5850	4–4½″	3–4½″	2–4½″	2–3½″	2–3″	3–4½″	2–4½″	2–3½″	2–3″	2–3″
200	6000	4–4½″	3–4½″	2–4½″	2–3½″	2–3″	3–4½″	2–4½″	2–3½″	2–3″	2–3″
205	6150	4–4½″	3–4½″	2–4½″	2–3½″	2–3½″	3–4½″	3–4″	2–3½″	2–3″	2–3″
210	6300	4–4½″	3–4½″	2–4½″	2–4″	2–3½″	3–4½″	3–4″	2–3½″	2–3″	2–3″
215	6450	4–4½″	3–4½″	2–4½″	2–4″	2–3½″	3–4½″	3–4″	2–4″	2–3″	2–3″
220	6600	5–4½″	4–4″	2–4½″	2–4″	2–3½″	3–4½″	3–4″	2–4″	2–3″	2–3″
225	6750	5–4½″	4–4″	2–4½″	2–4″	2–3½″	3–4½″	3–4″	2–4″	2–3½″	2–3″
230	6900	5–4½″	4–4″	2–4½″	2–4″	2–3½″	4–4″	3–4″	2–4″	2–3½″	2–3″
235	7050	5–4½″	4–4½″	3–4″	2–4″	2–3½″	4–4″	3–4″	2–4″	2–3½″	2–3″
240	7200	5–4½″	4–4½″	3–4″	2–4″	2–3½″	4–4″	3–4″	2–4″	2–3½″	2–3″
245	7350	5–4½″	4–4½″	3–4″	2–4″	2–3½″	4–4½″	3–4½″	2–4″	2–3½″	2–3″
250	7500	5–4½″	4–4½″	3–4″	2–4″	2–3½″	4–4½″	3–4½″	2–4″	2–3½″	2–3″

See explanatory notes on Page 51.

SAFETY VALVES FOR FIRE TUBE BOILERS

(For Pressures in Excess of 100 lbs.)

Nominal H. P. Rating	Required Capacity (Lbs. per hr.)	NUMBER AND DIAMETER OF SAFETY VALVES REQUIRED WITH AVERAGE LIFT											
		BEVEL SEAT						FLAT SEAT					
		125 lbs.	150 lbs.	175 lbs.	200 lbs.	225 lbs.	250 lbs.	125 lbs.	150 lbs.	175 lbs.	200 lbs.	225 lbs.	250 lbs.
50	2500	2–2″	2–1½″	2–1½″	2–1½″	2–1¼″	2–1¼″	2–1½″	2–1¼″	2–1¼″	2–1″	2–1″	2–1″
55	2750	2–2″	2–2″	2–1½″	2–1½″	2–1½″	2–1¼″	2–1½″	2–1½″	2–1¼″	2–1¼″	2–1″	2–1″
60	3000	2–2″	2–2″	2–1½″	2–1½″	2–1½″	2–1½″	2–1½″	2–1½″	2–1½″	2–1¼″	2–1¼″	2–1″
65	3250	2–2″	2–2″	2–2″	2–1½″	2–1½″	2–1½″	2–2″	2–1½″	2–1½″	2–1¼″	2–1¼″	2–1″
70	3500	2–2″	2–2″	2–2″	2–1½″	2–1½″	2–1½″	2–2″	2–1½″	2–1½″	2–1½″	2–1¼″	2–1¼″
75	3750	2–2½″	2–2″	2–2″	2–2″	2–1½″	2–1½″	2–2″	2–1½″	2–1½″	2–1½″	2–1½″	2–1¼″
80	4000	2–2½″	2–2″	2–2″	2–2″	2–2″	2–1½″	2–2″	2–2″	2–1½″	2–1½″	2–1½″	2–1¼″
85	4250	2–2½″	2–2″	2–2″	2–2″	2–2″	2–1½″	2–2″	2–2″	2–1½″	2–1½″	2–1½″	2–1½″
90	4500	2–2½″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–2″	2–2″	2–2″	2–1½″	2–1½″	2–1½″
95	4750	2–3″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–2″	2–2″	2–2″	2–1½″	2–1½″	2–1½″
100	5000	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–2″	2–2″	2–2″	2–1½″	2–1½″
105	5250	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″	2–2½″	2–2″	2–2″	2–2″	2–1½″	2–1½″
110	5500	2–3″	2–3″	2–2½″	2–2″	2–2″	2–2″	2–2½″	2–2″	2–2″	2–2″	2–1½″	2–1½″
115	5750	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–1½″
120	6000	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–1½″
125	6250	2–3″	2–3″	2–3″	2–2½″	2–2″	2–2″	2–2½″	2–2½″	2–2″	2–2″	2–2″	2–2″
130	6500	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–3″	2–2½″	2–2″	2–2″	2–2″	2–2″
135	6750	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–3″	2–2½″	2–2″	2–2″	2–2″	2–2″
140	7000	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2½″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″
145	7250	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″
150	7500	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″
155	7750	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–3″	2–3″	2–2½″	2–2″	2–2″	2–2″
160	8000	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″
165	8250	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″
170	8500	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″
175	8750	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2″	2–2″
180	9000	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″
185	9250	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″
190	9500	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″
195	9750	2–4″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″
200	10000	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″
205	10250	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″
210	10500	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″
215	10750	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″
220	11000	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″
225	11250	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″
230	11500	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″
235	11750	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″
240	12000	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″
245	12250	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″
250	12500	2–4½″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″

See explanatory notes on Page 51.

SAFETY VALVES FOR WATER TUBE BOILERS

Bevel Seat

Nominal Rated Horse-power	Required Capacity (Lbs. per Hr.)	Number and Diameter of Safety Valves Required with Average Lift								
		100 lbs.	125 lbs.	150 lbs.	175 lbs.	200 lbs.	225 lbs.	250 lbs.	275 lbs.	300 lbs.
100	6000	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″	2–2″
125	7500	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″
150	9000	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″
175	10500	2–4½″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″
200	12000	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″
225	13500	3–4″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″
250	15000	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″
275	16500	3–4½″	3–4″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3½″	2–3″
300	18000	3–4½″	3–4″	3–4″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3½″
325	19500	4–4″	3–4½″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–3½″	2–3½″
350	21000	4–4½″	3–4½″	3–4″	3–4	2–4½″	2–4″	2–4″	2–4″	2–3½″
375	22500	4–4½″	4–4″	3–4½″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–4″
400	24000	4–4½″	4–4″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4″	2–4″
425	25500		4–4½″	3–4½″	3–4½″	3–4″	2–4½″	2–4½″	2–4½″	2–4″
450	27000		4–4½″	4–4″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4″
475	28500		4–4½″	4–4″	3–4½″	3–4½″	3–4″	2–4½″	2–4½″	2–4½″
500	30000		4–4½″	4–4½″	3–4½″	3–4½″	3–4″	3–4″	2–4½″	2–4½″
525	31500			4–4½″	4–4″	3–4½″	3–4″	3–4″	3–4″	2–4½″
550	33000			4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″	2–4½″
575	34500			4–4½″	4–4½″	3–4½″	3–4½″	3–4″	3–4″	3–4″
600	36000				4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″
625	37500				4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″
650	39000				4–4½″	4–4½″	3–4½″	3–4½″	3–4½″	3–4″
675	40500				4–4½″	4–4½″	4–4″	3–4½″	3–4½″	3–4″
700	42000					4–4½″	4–4″	3–4½″	3–4½″	3–4½″
725	43500					4–4½″	4–4½″	4–4″	3–4½″	3–4½″
750	45000					4–4½″	4–4½″	4–4″	3–4½″	3–4½″
775	46500					4–4½″	4–4½″	4–4½″	4–4″	3–4½″
800	48000						4–4½″	4–4½″	4–4″	3–4½″
825	49500						4–4½″	4–4½″	4–4″	3–4½″
850	51000						4–4½″	4–4½″	4–4½″	3–4½″
875	52500							4–4½″	4–4½″	4–4″
900	54000							4–4½″	4–4½″	4–4½″
925	55500							4–4½″	4–4½″	4–4½″
950	57000							4–4½″	4–4½″	4–4½″
975	58500								4–4½″	4–4½″
1000	60000								4–4½″	4–4½″

See explanatory notes on Page 51.

SAFETY VALVES FOR WATER-TUBE BOILERS (Concluded)

Flat Seat

Nominal Rated Horse-power	Required Capacity (Lbs. per Hr.)	Number and Diameter of Safety Valves Required with Average Lift								
		100 lbs.	125 lbs.	150 lbs.	175 lbs.	200 lbs.	225 lbs.	250 lbs.	275 lbs.	300 lbs.
100	6000	2–3″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–1½″	2–1½″	2–1½″
125	7500	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″	2–2″	2–2″	2–2″
150	9000	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2½″	2–2″	2–2″
175	10500	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2″	2–2″
200	12000	2–4″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–2½″	2–2½″	2–2½″
225	13500	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″	2–2½″
250	15000	2–4½″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″	2–3″
275	16500	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″	2–3″
300	18000	3–4″	2–4½″	2–4″	2–3½″	2–3½″	2–3½″	2–3″	2–3″	2–3″
325	19500	3–4″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″	2–3″
350	21000	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3″	2–3″
375	22500	3–4½″	3–4″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3½″	2–3″
400	24000	3–4½″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3½″
425	25500	3–4½″	3–4″	3–4″	2–4½″	2–4″	2–4″	2–3½″	2–3½″	2–3½″
450	27000	4–4″	3–4½″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–3½″	2–3½″
475	28500	4–4½″	3–4½″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–4″	2–3½″
500	30000	4–4½″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–3½″
525	31500	4–4½″	3–4½″	3–4½″	3–4″	2–4½″	2–4½″	2–4″	2–4″	2–4″
550	33000	4–4½″	4–4″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4″	2–4″
575	34500	4–4½″	4–4½″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4″	2–4″
600	36000		4–4½″	3–4½″	3–4½″	3–4″	2–4½″	2–4½″	2–4½″	2–4″
625	37500		4–4½″	3–4½″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4″
650	39000		4–4½″	4–4″	3–4½″	3–4″	3–4″	2–4½″	2–4½″	2–4½″
675	40500		4–4½″	4–4½″	3–4½″	3–4½″	3–4″	3–4″	2–4½″	2–4½″
700	42000		4–4½″	4–4½″	3–4½″	3–4½″	3–4″	3–4″	2–4½″	2–4½″
725	43500			4–4½″	4–4″	3–4½″	3–4″	3–4″	2–4½″	2–4½″
750	45000			4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″	2–4½″
775	46500			4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″	2–4½″
800	48000			4–4½″	4–4½″	3–4½″	3–4½″	3–4″	3–4″	3–4″
825	49500				4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″
850	51000				4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″
875	52500				4–4½″	4–4″	3–4½″	3–4½″	3–4″	3–4″
900	54000				4–4½″	4–4½″	3–4½″	3–4½″	3–4½″	3–4″
925	55500				4–4½″	4–4½″	4–4″	3–4½″	3–4½″	3–4″
950	57000				4–4½″	4–4½″	4–4″	3–4½″	3–4½″	3–4″
975	58500					4–4½″	4–4″	3–4½″	3–4½″	3–4½″
1000	60000					4–4½″	4–4½″	3–4½″	3–4½″	3–4½″

See explanatory notes on Page 51.

Drilling and Other Details for Flanges and Fittings

(American Standard)

PRESSURES NOT EXCEEDING 125 LBS.

Pipe Size	Diameter of Flanges	Thickness of Flanges	Number of Holes	Size of Holes	Diameter of Bolt Circle	Size of Gaskets
1″	4″	7/16″	4	1/2″	3″	1″ x 2 1/2″
1 1/4″	4 1/2″	1/2″	4	1/2″	3 3/8″	1 1/4″ x 2 7/8″
1 1/2″	5″	9/16″	4	5/8″	3 7/8″	1 1/2″ x 3 1/4″
2″	6″	5/8″	4	3/4″	4 3/4″	2″ x 4″
2 1/2″	7″	11/16″	4	3/4″	5 1/2″	2 1/2″ x 4 3/4″
3″	7 1/2″	3/4″	4	3/4″	6″	3″ x 5 1/4″
3 1/2″	8 1/2″	13/16″	4	3/4″	7″	3 1/2″ x 6 1/4″
4″	9″	15/16″	8	3/4″	7 1/2″	4″ x 6 3/4″
4 1/2″	9 1/4″	15/16″	8	7/8″	7 3/4″	4 1/2″ x 6 7/8″
5″	10″	15/16″	8	7/8″	8 1/2″	5″ x 7 5/8″
6″	11″	1″	8	7/8″	9 1/2″	6″ x 8 5/8″
7″	12 1/2″	1 1/16″	8	7/8″	10 3/4″	7″ x 9 7/8″
8″	13 1/2″	1 1/8″	8	7/8″	11 3/4″	8″ x 10 7/8″
9″	15″	1 1/8″	12	7/8″	13 1/4″	9″ x 12 3/8″
10″	16″	1 3/16″	12	1″	14 1/4″	10″ x 13 1/4″
12″	19″	1 1/4″	12	1″	17″	12″ x 16″
14″	21″	1 3/8″	12	1 1/8″	18 3/4″	14″ x 17 5/8″

125 LBS. TO 250 LBS. PRESSURE

Pipe Size	Diameter of Flanges	Thickness of Flanges	Number of Holes	Size of Holes	Diameter of Bolt Circle	Size of Gaskets
1″	4 1/2″	11/16″	4	5/8″	3 1/4″	1″ x 2 5/8″
1 1/4″	5″	3/4″	4	5/8″	3 3/4″	1 1/4″ x 3 1/8″
1 1/2″	6″	13/16″	4	3/4″	4 1/2″	1 1/2″ x 3 3/4″
2″	6 1/2″	7/8″	4	3/4″	5″	2″ x 4 1/4″
2 1/2″	7 1/2″	1″	4	7/8″	5 7/8″	2 1/2″ x 5″
3″	8 1/4″	1 1/8″	8	7/8″	6 5/8″	3″ x 5 3/4″
3 1/2″	9″	1 3/16″	8	7/8″	7 1/4″	3 1/2″ x 6 3/8″
4″	10″	1 1/4″	8	7/8″	7 7/8″	4″ x 7″
4 1/2″	10 1/2″	1 5/16″	8	7/8″	8 1/2″	4 1/2″ x 7 5/8″
5″	11″	1 3/8″	8	7/8″	9 1/4″	5″ x 8 3/8″
6″	12 1/2″	1 7/16″	12	7/8″	10 5/8″	6″ x 9 3/4″
7″	14″	1 1/2″	12	1″	11 7/8″	7″ x 10 7/8″
8″	15″	1 5/8″	12	1″	13″	8″ x 12″
9″	16 1/4″	1 3/4″	12	1 1/8″	14″	9″ x 12 7/8″
10″	17 1/2″	1 7/8″	16	1 1/8″	15 1/4″	10″ x 14 1/8″
12″	20 1/2″	2″	16	1 1/4″	17 3/4″	12″ x 16 1/2″
14″	23″	2 1/8″	20	1 1/4″	20 1/4″	13 1/4″ x 19″

Minimum Number of Pipe Threads for Connections to Boilers

Size of Pipe Connection (Inches)	1 and 1/4	1 1/2 and 2	2 1/2 to 4 Inclusive	4 1/2 to 6 Inclusive	7 and 8	9 and 10	12
Number of threads per inch	11 1/2	11 1/2	8	8	8	8	8
Minimum number of threads required in opening	4	5	7	8	10	12	13
Minimum thickness of material required to give above number of threads (Inches)	0.348	0.435	0.875	1.000	1.250	1.500	1.625

Decimal Equivalents of Common Fractions

Common Fraction	Decimal Equivalent	Common Fraction	Decimal Equivalent	Common Fraction	Decimal Equivalent	Common Fraction	Decimal Equivalent
1/16	0.0625	1/32	0.03125	1/64	0.015625	33/64	0.515625
1/8	.1250	3/32	.09375	3/64	.046875	35/64	.546875
3/16	.1875	5/32	.15625	5/64	.078125	37/64	.578125
1/4	.2500	7/32	.21875	7/64	.109375	39/64	.609375
5/16	0.3125	9/32	0.28125	9/64	0.140625	41/64	0.640625
3/8	.3750	11/32	.34375	11/64	.171875	43/64	.671875
7/16	.4375	13/32	.40625	13/64	.203125	45/64	.703125
1/2	.5000	15/32	.46875	15/64	.234375	47/64	.734375
9/16	0.5625	17/32	0.53125	17/64	0.265625	49/64	0.765625
5/8	.6250	19/32	.59375	19/64	.296875	51/64	.796875
11/16	.6875	21/32	.65625	21/64	.328125	53/64	.828125
3/4	.7500	23/32	.71875	23/64	.359375	55/64	.859375
13/16	0.8125	25/32	0.78125	25/64	0.390625	57/64	0.890625
7/8	.8750	27/32	.84375	27/64	.421875	59/64	.921875
15/16	.9375	29/32	.90625	29/64	.453125	61/64	.953125
1	1.0000	31/32	.96875	31/64	.484375	63/64	.984375

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
1/32	0.0982	0.00077	1 1/32	3.2398	0.8352	2 1/32	6.3814	3.2405
1/16	.1964	.00307	1 1/16	3.3379	.8866	2 1/16	6.4795	3.3410
3/32	.2945	.00690	1 3/32	3.4361	.9396	2 3/32	6.5777	3.4430
1/8	.3927	.01227	1 1/8	3.5343	.9940	2 1/8	6.6759	3.5466
5/32	0.4909	0.01918	1 5/32	3.6325	1.0500	2 5/32	6.7741	3.6516
3/16	.5890	.02761	1 3/16	3.7306	1.1075	2 3/16	6.8722	3.7583
7/32	.6872	.03758	1 7/32	3.8288	1.1666	2 7/32	6.9704	3.8664
1/4	.7854	.04909	1 1/4	3.9270	1.2272	2 1/4	7.0686	3.9761
9/32	0.8836	0.06213	1 9/32	4.0252	1.2893	2 9/32	7.1668	4.0873
5/16	.9818	.07670	1 5/16	4.1233	1.3530	2 5/16	7.2649	4.2000
11/32	1.0799	.09281	1 11/32	4.2215	1.4182	2 11/32	7.3631	4.3143
3/8	1.1781	.11045	1 3/8	4.3197	1.4849	2 3/8	7.4613	4.4301
13/32	1.2763	0.12962	1 13/32	4.4179	1.5532	2 13/32	7.5595	4.5475
7/16	1.3744	.15033	1 7/16	4.5160	1.6230	2 7/16	7.6576	4.6664
15/32	1.4726	.17258	1 15/32	4.6142	1.6943	2 15/32	7.7558	4.7868
1/2	1.5708	.19635	1 1/2	4.7124	1.7672	2 1/2	7.8540	4.9087
17/32	1.6690	0.22166	1 17/32	4.8106	1.8415	2 17/32	7.9522	5.0322
9/16	1.7671	.24850	1 9/16	4.9087	1.9175	2 9/16	8.0503	5.1572
19/32	1.8653	.27688	1 19/32	5.0069	1.9949	2 19/32	8.1485	5.2838
5/8	1.9635	.30680	1 5/8	5.1051	2.0739	2 5/8	8.2467	5.4119
21/32	2.0617	0.33824	1 21/32	5.2033	2.1545	2 21/32	8.3449	5.5415
11/16	2.1598	.37122	1 11/16	5.3014	2.2365	2 11/16	8.4430	5.6727
23/32	2.2580	.40574	1 23/32	5.3996	2.3202	2 23/32	8.5412	5.8054
3/4	2.3562	.44179	1 3/4	5.4978	2.4053	2 3/4	8.6394	5.9396
25/32	2.4544	0.47937	1 25/32	5.5960	2.4920	2 25/32	8.7376	6.0753
13/16	2.5525	.51849	1 13/16	5.6941	2.5802	2 13/16	8.8357	6.2126
27/32	2.6507	.55914	1 27/32	5.7923	2.6699	2 27/32	8.9339	6.3515
7/8	2.7489	.60132	1 7/8	5.8905	2.7612	2 7/8	9.0321	6.4918
29/32	2.8471	0.64504	1 29/32	5.9887	2.8540	2 29/32	9.1303	6.6337
15/16	2.9452	.69029	1 15/16	6.0868	2.9483	2 15/16	9.2284	6.7771
31/32	3.0434	.73708	1 31/32	6.1850	3.0442	2 31/32	9.3266	6.9221
1	3.1416	.78540	2	6.2832	3.1416	3	9.4248	7.0686

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
3	9.4248	7.0686	5	15.7080	19.6350	7	21.9911	38.4845
3 1/16	9.6211	7.3662	5 1/16	15.9043	20.1289	7 1/16	22.1875	39.1748
3 1/8	9.8175	7.6699	5 1/8	16.1007	20.6290	7 1/8	22.3838	39.8712
3 3/16	10.0138	7.9798	5 3/16	16.2970	21.1352	7 3/16	22.5802	40.5738
3 1/4	10.2102	8.2958	5 1/4	16.4934	21.6475	7 1/4	22.7765	41.2825
3 5/16	10.4065	8.6179	5 5/16	16.6897	22.1660	7 5/16	22.9729	41.9973
3 3/8	10.6029	8.9462	5 3/8	16.8861	22.6906	7 3/8	23.1692	42.7183
3 7/16	10.7992	9.2806	5 7/16	17.0824	23.2214	7 7/16	23.3656	43.4454
3 1/2	10.9956	9.6211	5 1/2	17.2788	23.7583	7 1/2	23.5619	44.1786
3 9/16	11.1919	9.9678	5 9/16	17.4751	24.3013	7 9/16	23.7583	44.9180
3 5/8	11.3883	10.3206	5 5/8	17.6715	24.8505	7 5/8	23.9546	45.6635
3 11/16	11.5846	10.6796	5 11/16	17.8678	25.4058	7 11/16	24.1510	46.4152
3 3/4	11.7810	11.0447	5 3/4	18.0642	25.9672	7 3/4	24.3473	47.1730
3 13/16	11.9773	11.4159	5 13/16	18.2605	26.5348	7 13/16	24.5437	47.9369
3 7/8	12.1737	11.7932	5 7/8	18.4569	27.1085	7 7/8	24.7400	48.7070
3 15/16	12.3700	12.1767	5 15/16	18.6532	27.6884	7 15/16	24.9364	49.4831
4	12.5664	12.5664	6	18.8496	28.2743	8	25.1327	50.2655
4 1/16	12.7627	12.9621	6 1/16	19.0459	28.8665	8 1/16	25.3291	51.0539
4 1/8	12.9591	13.3640	6 1/8	19.2423	29.4647	8 1/8	25.5254	51.8486
4 3/16	13.1554	13.7721	6 3/16	19.4386	30.0691	8 3/16	25.7218	52.6493
4 1/4	13.3518	14.1863	6 1/4	19.6350	30.6796	8 1/4	25.9181	53.4562
4 5/16	13.5481	14.6066	6 5/16	19.8313	31.2963	8 5/16	26.1145	54.2692
4 3/8	13.7445	15.0330	6 3/8	20.0277	31.9191	8 3/8	26.3108	55.0883
4 7/16	13.9408	15.4656	6 7/16	20.2240	32.5480	8 7/16	26.5072	55.9136
4 1/2	14.1372	15.9043	6 1/2	20.4204	33.1831	8 1/2	26.7035	56.7450
9/16	14.3335	16.3492	6 9/16	20.6167	33.8243	8 9/16	26.8999	57.5826
4 5/8	14.5299	16.8002	6 5/8	20.8131	34.4716	8 5/8	27.0962	58.4263
4 11/16	14.7262	17.2573	6 11/16	21.0094	35.1251	8 11/16	27.2926	59.2761
4 3/4	14.9226	17.7205	6 3/4	21.2058	35.7847	8 3/4	27.4889	60.1320
4 13/16	15.1189	18.1899	6 13/16	21.4021	36.4504	8 13/16	27.6853	60.9941
4 7/8	15.3153	18.6655	6 7/8	21.5984	37.1223	8 7/8	27.8816	61.8624
4 15/16	15.5116	19.1472	6 15/16	21.7948	37.8004	8 15/16	28.0780	62.7367
5	15.7080	19.6350	7	21.9911	38.4845	9	28.2743	63.6173

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
9	28.2743	63.6173	**11**	34.5575	95.0332	**13**	40.8407	132.7323
9 1/16	28.4707	64.5039	**11** 1/16	34.7539	96.1162	**13** 1/16	41.0371	134.0116
9 1/8	28.6670	65.3967	**11** 1/8	34.9502	97.2053	**13** 1/8	41.2334	135.2971
9 3/16	28.8634	66.2956	**11** 3/16	35.1466	98.3006	**13** 3/16	41.4298	136.5887
9 1/4	29.0597	67.2006	**11** 1/4	35.3429	99.4020	**13** 1/4	41.6261	137.8865
9 5/16	29.2561	68.1118	**11** 5/16	35.5393	100.5095	**13** 5/16	41.8225	139.1903
9 3/8	29.4524	69.0291	**11** 3/8	35.7356	101.6232	**13** 3/8	42.0188	140.5004
9 7/16	29.6488	69.9526	**11** 7/16	35.9320	102.7430	**13** 7/16	42.2152	141.8165
9 1/2	29.8451	70.8822	**11** 1/2	36.1283	103.8689	**13** 1/2	42.4115	143.1388
9 9/16	30.0415	71.8179	**11** 9/16	36.3247	105.0010	**13** 9/16	42.6078	144.4672
9 5/8	30.2378	72.7598	**11** 5/8	36.5210	106.1392	**13** 5/8	42.8042	145.8018
9 11/16	30.4342	73.7078	**11** 11/16	36.7174	107.2835	**13** 11/16	43.0005	147.1425
9 3/4	30.6305	74.6619	**11** 3/4	36.9137	108.4340	**13** 3/4	43.1969	148.4893
9 13/16	30.8269	75.6222	**11** 13/16	37.1101	109.5907	**13** 13/16	43.3932	149.8423
9 7/8	31.0232	76.5886	**11** 7/8	37.3064	110.7534	**13** 7/8	43.5896	151.2014
9 15/16	31.2196	77.5611	**11** 15/16	37.5028	111.9223	**13** 15/16	43.7859	152.5667
10	31.4159	78.5398	**12**	37.6991	113.0973	**14**	43.9823	153.9380
10 1/16	31.6123	79.5246	**12** 1/16	37.8955	114.2785	**14** 1/16	44.1786	155.3156
10 1/8	31.8086	80.5156	**12** 1/8	38.0918	115.4658	**14** 1/8	44.3750	156.6992
10 3/16	32.0050	81.5127	**12** 3/16	38.2882	116.6592	**14** 3/16	44.5713	158.0890
10 1/4	32.2013	82.5159	**12** 1/4	38.4845	117.8588	**14** 1/4	44.7677	159.4849
10 5/16	32.3977	83.5253	**12** 5/16	38.6809	119.0645	**14** 5/16	44.9640	160.8870
10 3/8	32.5940	84.5407	**12** 3/8	38.8772	120.2764	**14** 3/8	45.1604	162.2952
10 7/16	32.7904	85.5624	**12** 7/16	39.0736	121.4943	**14** 7/16	45.3567	163.7095
10 1/2	32.9867	86.5901	**12** 1/2	39.2699	122.7185	**14** 1/2	45.5531	165.1300
10 9/16	33.1831	87.6240	**12** 9/16	39.4663	123.9487	**14** 9/16	45.7494	166.5566
10 5/8	33.3794	88.6641	**12** 5/8	39.6626	125.1851	**14** 5/8	45.9458	167.9893
10 11/16	33.5758	89.7103	**12** 11/16	39.8590	126.4276	**14** 11/16	46.1421	169.4282
10 3/4	33.7721	90.7626	**12** 3/4	40.0553	127.6763	**14** 3/4	46.3385	170.8732
10 13/16	33.9685	91.8210	**12** 13/16	40.2517	128.9311	**14** 13/16	46.5348	172.3243
10 7/8	34.1648	92.8856	**12** 7/8	40.4480	130.1920	**14** 7/8	46.7312	173.7816
10 15/16	34.3612	93.9563	**12** 15/16	40.6444	131.4591	**14** 15/16	46.9275	175.2450
11	34.5575	95.0332	**13**	40.8407	132.7323	**15**	47.1239	176.7146

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
15	47.124	176.715	**20**	62.832	314.159	**25**	78.540	490.874
1/8	47.517	179.672	1/8	63.225	318.099	1/8	78.933	495.795
1/4	47.909	182.654	1/4	63.617	322.062	1/4	79.325	500.740
3/8	48.302	185.661	3/8	64.010	326.051	3/8	79.718	505.710
1/2	48.695	188.692	1/2	64.403	330.064	1/2	80.111	510.705
5/8	49.087	191.748	5/8	64.795	334.101	5/8	80.503	515.724
3/4	49.480	194.828	3/4	65.188	338.163	3/4	80.896	520.768
7/8	49.873	197.933	7/8	65.581	342.250	7/8	81.289	525.836
16	50.265	201.062	**21**	65.973	346.361	**26**	81.681	530.929
1/8	50.658	204.216	1/8	66.366	350.496	1/8	82.074	536.046
1/4	51.051	207.394	1/4	66.759	354.656	1/4	82.467	541.188
3/8	51.444	210.597	3/8	67.152	358.841	3/8	82.860	546.355
1/2	51.836	213.825	1/2	67.544	363.050	1/2	83.252	551.546
5/8	52.229	217.077	5/8	67.937	367.284	5/8	83.645	556.761
3/4	52.622	220.353	3/4	68.330	371.542	3/4	84.038	562.001
7/8	53.014	223.654	7/8	68.722	375.825	7/8	84.430	567.266
17	53.407	226.980	**22**	69.115	380.133	**27**	84.823	572.555
1/8	53.800	230.330	1/8	69.508	384.465	1/8	85.216	577.869
1/4	54.192	233.705	1/4	69.900	388.821	1/4	85.608	583.207
3/8	54.585	237.104	3/8	70.293	393.202	3/8	86.001	588.570
1/2	54.978	240.528	1/2	70.686	397.608	1/2	86.394	593.957
5/8	55.371	243.977	5/8	71.079	402.038	5/8	86.786	599.369
3/4	55.763	247.450	3/4	71.471	406.493	3/4	87.179	604.805
7/8	56.156	250.947	7/8	71.864	410.972	7/8	87.572	610.266
18	56.549	254.469	**23**	72.257	415.476	**28**	87.965	615.752
1/8	56.941	258.016	1/8	72.649	420.004	1/8	88.357	621.262
1/4	57.334	261.587	1/4	73.042	424.557	1/4	88.750	626.797
3/8	57.727	265.182	3/8	73.435	429.134	3/8	89.143	632.356
1/2	58.119	268.802	1/2	73.827	433.736	1/2	89.535	637.940
5/8	58.512	272.447	5/8	74.220	438.363	5/8	89.928	643.548
3/4	58.905	276.117	3/4	74.613	443.014	3/4	90.321	649.180
7/8	59.298	279.811	7/8	75.006	447.689	7/8	90.714	654.838
19	59.690	283.529	**24**	75.398	452.389	**29**	91.106	660.520
1/8	60.083	287.272	1/8	75.791	457.114	1/8	91.499	666.226
1/4	60.476	291.039	1/4	76.184	461.863	1/4	91.892	671.957
3/8	60.868	294.831	3/8	76.576	466.637	3/8	92.284	677.713
1/2	61.261	298.648	1/2	76.969	471.435	1/2	92.677	683.493
5/8	61.654	302.489	5/8	77.362	476.258	5/8	93.070	689.297
3/4	62.046	306.355	3/4	77.754	481.105	3/4	93.462	695.126
7/8	62.439	310.245	7/8	78.147	485.977	7/8	93.855	700.980
20	62.832	314.159	**25**	78.540	490.874	**30**	94.248	706.858

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
30	94.248	706.86	**35**	109.956	962.11	**40**	125.664	1256.64
1/8	94.640	712.76	1/8	110.348	969.00	1/8	126.056	1264.50
1/4	95.033	718.69	1/4	110.741	975.91	1/4	126.449	1272.39
3/8	95.426	724.64	3/8	111.134	982.84	3/8	126.842	1280.31
1/2	95.819	730.62	1/2	111.526	989.80	1/2	127.234	1288.25
5/8	96.211	736.62	5/8	111.919	996.78	5/8	127.627	1296.21
3/4	96.604	742.64	3/4	112.312	1003.79	3/4	128.020	1304.20
7/8	96.997	748.69	7/8	112.705	1010.82	7/8	128.413	1312.22
31	97.389	754.77	**36**	113.097	1017.88	**41**	128.805	1320.25
1/8	97.782	760.87	1/8	113.490	1024.96	1/8	129.198	1328.32
1/4	98.175	766.99	1/4	113.883	1032.06	1/4	129.591	1336.40
3/8	98.568	773.14	3/8	114.275	1039.19	3/8	129.983	1344.52
1/2	98.960	779.31	1/2	114.668	1046.35	1/2	130.376	1352.65
5/8	99.353	785.51	5/8	115.061	1053.53	5/8	130.769	1360.81
3/4	99.746	791.73	3/4	115.454	1060.73	3/4	131.162	1369.00
7/8	100.138	797.98	7/8	115.846	1067.96	7/8	131.554	1377.21
32	100.531	804.25	**37**	116.239	1075.21	**42**	131.947	1385.44
1/8	100.924	810.54	1/8	116.632	1082.49	1/8	132.340	1393.70
1/4	101.316	816.86	1/4	117.024	1089.79	1/4	132.732	1401.98
3/8	101.709	823.21	3/8	117.417	1097.12	3/8	133.125	1410.29
1/2	102.102	829.58	1/2	117.810	1104.47	1/2	133.518	1418.62
5/8	102.494	835.97	5/8	118.202	1111.84	5/8	133.910	1426.98
3/4	102.887	842.39	3/4	118.595	1119.24	3/4	134.303	1435.36
7/8	103.280	848.83	7/8	118.988	1126.66	7/8	134.696	1443.77
33	103.673	855.30	**38**	119.381	1134.11	**43**	135.088	1452.20
1/8	104.065	861.79	1/8	119.773	1141.59	1/8	135.481	1460.66
1/4	104.458	868.31	1/4	120.166	1149.09	1/4	135.874	1469.14
3/8	104.851	874.85	3/8	120.559	1156.61	3/8	136.267	1477.64
1/2	105.243	881.41	1/2	120.951	1164.16	1/2	136.659	1486.17
5/8	105.636	888.00	5/8	121.344	1171.73	5/8	137.052	1494.72
3/4	106.029	894.62	3/4	121.737	1179.32	3/4	137.445	1503.30
7/8	106.422	901.26	7/8	122.129	1186.94	7/8	137.837	1511.90
34	106.814	907.92	**39**	122.522	1194.59	**44**	138.230	1520.53
1/8	107.207	914.61	1/8	122.915	1202.26	1/8	138.623	1529.18
1/4	107.600	921.32	1/4	123.308	1209.96	1/4	139.016	1537.86
3/8	107.992	928.06	3/8	123.700	1217.67	3/8	139.408	1546.56
1/2	108.385	934.82	1/2	124.093	1225.42	1/2	139.801	1555.28
5/8	108.778	941.61	5/8	124.486	1233.19	5/8	140.194	1564.03
3/4	109.170	948.42	3/4	124.878	1240.98	3/4	140.586	1572.81
7/8	109.563	955.25	7/8	125.271	1248.80	7/8	140.979	1581.61
35	109.956	962.11	**40**	125.664	1256.64	**45**	141.372	1590.43

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
45	141.372	1590.43	**50**	157.080	1963.50	**55**	172.788	2375.83
1/8	141.764	1599.28	1/8	157.472	1973.33	1/8	173.180	2386.64
1/4	142.157	1608.15	1/4	157.865	1983.18	1/4	173.573	2397.48
3/8	142.550	1617.05	3/8	158.258	1993.06	3/8	173.966	2408.34
1/2	142.942	1625.97	1/2	158.650	2002.96	1/2	174.358	2419.22
5/8	143.335	1634.92	5/8	159.043	2012.89	5/8	174.751	2430.13
3/4	143.728	1643.89	3/4	159.436	2022.84	3/4	175.144	2441.07
7/8	144.121	1652.88	7/8	159.828	2032.82	7/8	175.536	2452.03
46	144.513	1661.90	**51**	160.221	2042.82	**56**	175.929	2463.01
1/8	144.906	1670.95	1/8	160.614	2052.85	1/8	176.322	2474.02
1/4	145.299	1680.02	1/4	161.007	2062.90	1/4	176.715	2485.05
3/8	145.691	1689.11	3/8	161.399	2072.97	3/8	177.107	2496.11
1/2	146.084	1698.23	1/2	161.792	2083.07	1/2	177.500	2507.19
5/8	146.477	1707.37	5/8	162.185	2093.20	5/8	177.893	2518.29
3/4	146.870	1716.54	3/4	162.577	2103.35	3/4	178.285	2529.42
7/8	147.262	1725.73	7/8	162.970	2113.52	7/8	178.678	2540.58
47	147.655	1734.94	**52**	163.363	2123.72	**57**	179.071	2551.76
1/8	148.048	1744.19	1/8	163.756	2133.94	1/8	179.464	2562.96
1/4	148.440	1753.45	1/4	164.148	2144.19	1/4	179.856	2574.19
3/8	148.833	1762.74	3/8	164.541	2154.46	3/8	180.249	2585.45
1/2	149.226	1772.05	1/2	164.934	2164.75	1/2	180.642	2596.73
5/8	149.618	1781.39	5/8	165.326	2175.08	5/8	181.034	2608.03
3/4	150.011	1790.76	3/4	165.719	2185.42	3/4	181.427	2619.35
7/8	150.404	1800.14	7/8	166.112	2195.79	7/8	181.820	2630.70
48	150.796	1809.56	**53**	166.504	2206.18	**58**	182.212	2642.08
1/8	151.189	1818.99	1/8	166.897	2216.60	1/8	182.605	2653.48
1/4	151.582	1828.46	1/4	167.290	2227.05	1/4	182.998	2664.91
3/8	151.974	1837.94	3/8	167.682	2237.52	3/8	183.390	2676.36
1/2	152.367	1847.45	1/2	168.075	2248.01	1/2	183.783	2687.83
5/8	152.760	1856.99	5/8	168.468	2258.53	5/8	184.176	2699.33
3/4	153.153	1866.55	3/4	168.861	2269.07	3/4	184.569	2710.85
7/8	153.545	1876.13	7/8	169.253	2279.63	7/8	184.961	2722.40
49	153.938	1885.74	**54**	169.646	2290.22	**59**	185.354	2733.97
1/8	154.331	1895.37	1/8	170.039	2300.84	1/8	185.747	2745.57
1/4	154.723	1905.03	1/4	170.431	2311.48	1/4	186.139	2757.19
3/8	155.116	1914.72	3/8	170.824	2322.14	3/8	186.532	2768.84
1/2	155.509	1924.42	1/2	171.217	2332.83	1/2	186.925	2780.51
5/8	155.902	1934.15	5/8	171.610	2343.54	5/8	187.318	2792.20
3/4	156.294	1943.91	3/4	172.002	2354.28	3/4	187.710	2803.92
7/8	156.687	1953.69	7/8	172.395	2365.04	7/8	188.103	2815.67
50	157.080	1963.50	**55**	172.788	2375.83	**60**	188.496	2827.43

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
60	188.496	2827.43	**65**	204.204	3318.31	**70**	219.911	3848.45
1/8	188.888	2839.23	1/8	204.596	3331.08	1/8	220.304	3862.21
1/4	189.281	2851.04	1/4	204.989	3343.88	1/4	220.697	3875.99
3/8	189.674	2862.89	3/8	205.382	3356.71	3/8	221.090	3889.80
1/2	190.066	2874.75	1/2	205.774	3369.55	1/2	221.482	3903.63
5/8	190.459	2886.65	5/8	206.167	3382.43	5/8	221.875	3917.48
3/4	190.852	2898.56	3/4	206.560	3395.33	3/4	222.268	3931.36
7/8	191.244	2910.50	7/8	206.952	3408.25	7/8	222.660	3945.26
61	191.637	2922.47	**66**	207.345	3421.19	**71**	223.053	3959.19
1/8	192.030	2934.46	1/8	207.738	3434.17	1/8	223.446	3973.15
1/4	192.423	2946.47	1/4	208.130	3447.17	1/4	223.838	3987.12
3/8	192.815	2958.51	3/8	208.523	3460.18	3/8	224.231	4001.13
1/2	193.208	2970.57	1/2	208.916	3473.23	1/2	224.624	4015.15
5/8	193.601	2982.66	5/8	209.309	3486.30	5/8	225.017	4029.20
3/4	193.993	2994.77	3/4	209.701	3499.39	3/4	225.409	4043.28
7/8	194.386	3006.91	7/8	210.094	3512.51	7/8	225.802	4057.38
62	194.779	3019.07	**67**	210.487	3525.65	**72**	226.195	4071.50
1/8	195.172	3031.26	1/8	210.879	3538.82	1/8	226.587	4085.65
1/4	195.564	3043.47	1/4	211.272	3552.01	1/4	226.980	4099.83
3/8	195.957	3055.70	3/8	211.665	3565.23	3/8	227.373	4114.03
1/2	196.350	3067.96	1/2	212.058	3578.47	1/2	227.766	4128.25
5/8	196.742	3080.25	5/8	212.450	3591.74	5/8	228.158	4142.50
3/4	197.135	3092.56	3/4	212.843	3605.03	3/4	228.551	4156.77
7/8	197.528	3104.89	7/8	213.236	3618.34	7/8	228.944	4171.07
63	197.920	3117.25	**68**	213.628	3631.68	**73**	229.336	4185.39
1/8	198.313	3129.63	1/8	214.021	3645.05	1/8	229.729	4199.73
1/4	198.706	3142.03	1/4	214.414	3658.43	1/4	230.122	4214.10
3/8	199.098	3154.47	3/8	214.806	3671.85	3/8	230.514	4228.50
1/2	199.491	3166.92	1/2	215.199	3685.28	1/2	230.907	4242.92
5/8	199.884	3179.40	5/8	215.592	3698.75	5/8	231.300	4257.36
3/4	200.276	3191.91	3/4	215.984	3712.23	3/4	231.692	4271.83
7/8	200.669	3204.44	7/8	216.377	3725.75	7/8	232.085	4286.32
64	201.062	3216.99	**69**	216.770	3739.28	**74**	232.478	4300.84
1/8	201.455	3229.57	1/8	217.163	3752.84	1/8	232.871	4315.38
1/4	201.847	3242.17	1/4	217.555	3766.43	1/4	233.263	4329.95
3/8	202.240	3254.80	3/8	217.948	3780.04	3/8	233.656	4344.54
1/2	202.633	3267.45	1/2	218.341	3793.67	1/2	234.049	4359.16
5/8	203.025	3280.13	5/8	218.733	3807.33	5/8	234.441	4373.80
3/4	203.418	3292.83	3/4	219.126	3821.01	3/4	234.834	4388.46
7/8	203.811	3305.56	7/8	219.519	3834.72	7/8	235.227	4403.15
65	204.204	3318.31	**70**	219.911	3848.45	**75**	235.619	4417.86

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
75	235.619	4417.86	**80**	251.327	5026.55	**85**	267.035	5674.50
1/8	236.012	4432.60	1/8	251.720	5042.27	1/8	267.428	5691.20
1/4	236.405	4447.37	1/4	252.113	5058.01	1/4	267.821	5707.93
3/8	236.798	4462.15	3/8	252.506	5073.78	3/8	268.214	5724.68
1/2	237.190	4476.97	1/2	252.898	5089.58	1/2	268.606	5741.46
5/8	237.583	4491.80	5/8	253.291	5105.39	5/8	268.999	5758.26
3/4	237.976	4506.66	3/4	253.684	5121.24	3/4	269.392	5775.08
7/8	238.368	4521.55	7/8	254.076	5137.10	7/8	269.784	5791.93
76	238.761	4536.46	**81**	254.469	5153.00	**86**	270.177	5808.80
1/8	239.154	4551.39	1/8	254.862	5168.91	1/8	270.570	5825.70
1/4	239.546	4566.35	1/4	255.254	5184.85	1/4	270.962	5842.63
3/8	239.939	4581.34	3/8	255.647	5200.82	3/8	271.355	5859.57
1/2	240.332	4596.35	1/2	256.040	5216.81	1/2	271.748	5876.55
5/8	240.724	4611.38	5/8	256.432	5232.83	5/8	272.140	5893.54
3/4	241.117	4626.44	3/4	256.825	5248.86	3/4	272.533	5910.56
7/8	241.510	4641.52	7/8	257.218	5264.93	7/8	272.926	5927.61
77	241.903	4656.63	**82**	257.611	5281.02	**87**	273.319	5944.68
1/8	242.295	4671.76	1/8	258.003	5297.13	1/8	273.711	5961.77
1/4	242.688	4686.91	1/4	258.396	5313.27	1/4	274.104	5978.89
3/8	243.081	4702.09	3/8	258.789	5329.43	3/8	274.497	5996.04
1/2	243.473	4717.30	1/2	259.181	5345.62	1/2	274.889	6013.20
5/8	243.866	4732.53	5/8	259.574	5361.83	5/8	275.282	6030.40
3/4	244.259	4747.78	3/4	259.967	5378.06	3/4	275.675	6047.62
7/8	244.652	4763.06	7/8	260.360	5394.32	7/8	276.068	6064.86
78	245.044	4778.36	**83**	260.752	5410.61	**88**	276.460	6082.12
1/8	245.437	4793.69	1/8	261.145	5426.92	1/8	276.853	6099.41
1/4	245.830	4809.04	1/4	261.538	5443.25	1/4	277.246	6116.73
3/8	246.222	4824.42	3/8	261.930	5459.61	3/8	277.638	6134.07
1/2	246.615	4839.82	1/2	262.323	5475.99	1/2	278.031	6151.44
5/8	247.008	4855.25	5/8	262.716	5492.40	5/8	278.424	6168.82
3/4	247.400	4870.70	3/4	263.108	5508.83	3/4	278.816	6186.24
7/8	247.793	4886.17	7/8	263.501	5525.29	7/8	279.209	6203.68
79	248.186	4901.67	**84**	263.894	5541.77	**89**	279.602	6221.14
1/8	248.578	4917.19	1/8	264.286	5558.28	1/8	279.994	6238.63
1/4	248.971	4932.74	1/4	264.679	5574.81	1/4	280.387	6256.14
3/8	249.364	4948.32	3/8	265.072	5591.36	3/8	280.780	6273.67
1/2	249.757	4963.91	1/2	265.465	5607.94	1/2	281.172	6291.24
5/8	250.149	4979.54	5/8	265.857	5624.54	5/8	281.565	6308.82
3/4	250.542	4995.18	3/4	266.250	5641.17	3/4	281.958	6326.43
7/8	250.935	5010.85	7/8	266.643	5657.82	7/8	282.351	6344.07
80	251.327	5026.55	**85**	267.035	5674.50	**90**	282.743	6361.73

Circumferences and Areas of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
90	282.743	6361.73	**95**	298.451	7088.22	**100**	314.159	7853.98
1/8	283.136	6379.41	1/8	298.844	7106.88	1/8	314.552	7873.63
1/4	283.529	6397.12	1/4	299.237	7125.57	1/4	314.945	7893.30
3/8	283.921	6414.85	3/8	299.629	7144.29	3/8	315.337	7913.00
1/2	284.314	6432.61	1/2	300.022	7163.03	1/2	315.730	7932.72
5/8	284.707	6450.39	5/8	300.415	7181.79	5/8	316.123	7952.46
3/4	285.100	6468.20	3/4	300.808	7200.58	3/4	316.516	7972.23
7/8	285.492	6486.03	7/8	301.200	7219.39	7/8	316.908	7992.03
91	285.885	6503.88	**96**	301.593	7238.23	**101**	317.301	8011.85
1/8	286.278	6521.76	1/8	301.986	7257.09	1/8	317.694	8031.69
1/4	286.670	6539.67	1/4	302.378	7275.98	1/4	318.086	8051.56
3/8	287.063	6557.60	3/8	302.771	7294.89	3/8	318.479	8071.45
1/2	287.456	6575.55	1/2	303.164	7313.82	1/2	318.872	8091.37
5/8	287.848	6593.53	5/8	303.556	7332.78	5/8	319.264	8111.31
3/4	288.241	6611.53	3/4	303.949	7351.77	3/4	319.657	8131.28
7/8	288.634	6629.56	7/8	304.342	7370.78	7/8	320.050	8151.27
92	289.027	6647.61	**97**	304.734	7389.81	**102**	320.442	8171.28
1/8	289.419	6665.69	1/8	305.127	7408.87	1/8	320.835	8191.32
1/4	289.812	6683.79	1/4	305.520	7427.95	1/4	321.228	8211.39
3/8	290.205	6701.91	3/8	305.913	7447.06	3/8	321.620	8231.48
1/2	290.597	6720.06	1/2	306.305	7466.19	1/2	322.013	8251.59
5/8	290.990	6738.24	5/8	306.698	7485.35	5/8	322.406	8271.73
3/4	291.383	6756.44	3/4	307.091	7504.53	3/4	322.799	8291.89
7/8	291.775	6774.66	7/8	307.483	7523.73	7/8	323.191	8312.08
93	292.168	6792.91	**98**	307.876	7542.96	**103**	323.584	8332.29
1/8	292.561	6811.18	1/8	308.269	7562.22	1/8	323.977	8352.53
1/4	292.954	6829.48	1/4	308.662	7581.50	1/4	324.369	8372.79
3/8	293.346	6847.80	3/8	309.054	7600.80	3/8	324.762	8393.07
1/2	293.739	6866.15	1/2	309.447	7620.13	1/2	325.155	8413.38
5/8	294.132	6884.52	5/8	309.840	7639.48	5/8	325.548	8433.72
3/4	294.524	6902.91	3/4	310.232	7658.86	3/4	325.940	8454.08
7/8	294.917	6921.33	7/8	310.625	7678.26	7/8	326.333	8474.46
94	295.310	6939.78	**99**	311.018	7697.69	**104**	326.726	8494.87
1/8	295.702	6958.25	1/8	311.410	7717.14	1/8	327.118	8515.30
1/4	296.095	6976.74	1/4	311.803	7736.61	1/4	327.511	8535.76
3/8	296.488	6995.26	3/8	312.196	7756.11	3/8	327.904	8556.24
1/2	296.880	7013.80	1/2	312.588	7775.64	1/2	328.296	8576.74
5/8	297.273	7032.37	5/8	312.981	7795.19	5/8	328.689	8597.28
3/4	297.666	7050.96	3/4	313.374	7814.76	3/4	329.082	8617.83
7/8	298.059	7069.58	7/8	313.767	7834.36	7/8	329.474	8638.41
95	298.451	7088.22	**100**	314.159	7853.98	**105**	329.867	8659.01